Augmented and Virtual Reality Technologies in the Future of Work: User Preferences and Design Principles

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Preface

This cumulative dissertation was drafted during my employment as a research assistant at the Department of Accounting and Information Systems between October 2018 and December 2021 at the University of Osnabrück. Throughout this period, I engaged as a fellow within the research training group “Vertrauen und Akzeptanz in erweiterten und virtuellen Arbeitswelten.” This project allowed me to engage in interdisciplinary studies on the design, use, and implications of augmented and virtual reality technologies in organizations. I would like to take this opportunity to thank the people who helped and supported me throughout.

First and foremost, my sincere thanks goes to my doctoral supervisor, Prof. Dr. Frank Teuteberg, for encouraging me to undertake this step and for supporting me along the way. During the production of this dissertation, he gave me the freedom to pursue my research interests and provided valuable methodological inspirations and constructive feedback. I am also grateful to Prof. Dr. Oliver Thomas, who served as a speaker for our research training group and agreed to co-supervise my dissertation.

Furthermore, I would like to thank my colleagues at the University of Osnabrück, who assisted my dissertation work with constructive discussions and amiable cooperation. My special thanks goes to Dr. Christian Fitte, Dr. Jan Heinrich Beinke, and Dr. Pascal Meier, who warmly welcomed me to the Department of Accounting and Information Systems and paved the way for a successful start to my employment. Furthermore, I would like to thank Mr. Eduard Anton, Dr. Jannis Vogel, Mr. Ludger Pöhler, and Dr. Thuy Duong Oesterreich, who shared their valuable expertise during inspiring and helpful discussions about emerging research phenomena and methodological issues. In addition, I am thankful to Mrs. Barbara Meierkord and Mrs. Marita Imhorst, who supported me in bureaucratic and linguistic matters.

Moreover, I would like to thank my family. In particular, I express gratitude to my girlfriend, Frauke, for her support throughout the research projects in this dissertation. Likewise, I would like to thank my parents, Birgit and Johannes, as well as my sisters, Anne and Marie, who have been instrumental in supporting me.

Lastly, my sincere thanks goes to my friends, particularly Arne, Clara, Daniel, Fabian, Jan, Jonas, Kieran, Lisa, Maxi, Rieke, and Sayed for their indispensable support and all the activities that helped me through the ups and downs during these times.

Osnabrück, June 2022 Julian Schuir

Notes on the Structure of the Document

This cumulative dissertation is organized into two parts. Part A presents an overview of the individual contributions by introducing the motivation and objectives, situating the individual contributions in a framework, and then summarizing and discussing these results. Part A thus constitutes a stand-alone contribution that includes a list of abbreviations, figures, tables, and references. In contrast, Part B comprises the individual contributions summarized in Part A. As such, Part B contains the original citation styles of the publications as well as their appendices and reference lists.

Contents

Part A: Introductory Overview

List of Abbreviations

2D	Two-dimensional
3D	Three-dimensional
AI	Artificial Intelligence
AR	Augmented Reality
BPMN	Business Process Model and Notation
CA	Conversational Agent
CNN	Convolutional Neural Network
COVID-19	Coronavirus Disease 2019
ECIS	European Conference on Information Systems
ID	Identifier
ICIS	International Conference on Information Systems
IT	Information Technology
IS	Information Systems
TAM	Technology Acceptance Model
VHB	Verband der Hochschullehrer der Betriebswirtschaft e.V.
WKWI	Wissenschaftliche Kommission Wirtschaftsinformatik
VR	Virtual Reality

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1 Introduction

1.1 Motivation

Immersive technologies, including augmented reality (AR) and virtual reality (VR), are expected to become prevalent in future work environments (Bhattacharyya and Nair 2019). In essence, these technologies "purposefully change or enhance the user's perception of reality" (Cavusoglu et al. 2019, p. 680). Thus, AR enhances the user's natural perception of the physical environment by superimposing virtual information onto the field of view in real time via smartphones or AR glasses (Azuma et al. 2001). In contrast, VR employs stereoscopic headsets to entirely immerse the user in a computer-generated environment that simulates real-world presence (Wohlgenannt et al. 2020). Both technologies can support a broad array of tasks, such as collaboration, design, maintenance, and training activities (Harborth and Kümpers 2021, Kortekamp et al. 2019). For instance, technicians wearing AR glasses can access task instructions superimposed on the physical environment to service a machine while working hands-free (Kammler et al. 2019), whereas geographically dispersed teams can leverage VR to collaborate in a shared virtual space and co-create products (Vogel et al. 2021). Given these capabilities, the implementation of AR and VR technologies is associated with versatile benefits, such as decreased costs, reduced physical risks, increased employee self-satisfaction, and lower resource consumption (Oesterreich and Teuteberg 2018; Steffen et al. 2019).

The idea of manipulating the user's perception of reality dates back to 1968, when the American scientist Ivan Sutherland (1968) pioneered his vision of "The Ultimate Display," which was a head-mounted display with a stereoscopic view. For the following five decades, the vision of affordable AR and VR technologies exceeded the existing technical capabilities (Kugler 2021). This notion changed when leading technology companies, including Google, Microsoft, and Facebook, began investing heavily in the technological ecosystem, resulting in the consumer market availability of wearable devices such as Google Glass, Microsoft HoloLens, and Oculus Quest (Anthes et al. 2016; Kugler 2021; Rauschnabel and Ro 2016). Forecasts anticipate that these rapid technological advances have paved the way for the diffusion of AR and VR in the workplace. The global market for AR and VR is projected to grow from US$ 30.7 billion in 2018 to US$ 296.9 billion in 2024 (Boston Consulting Group 2021), and PricewaterhouseCoopers (2021) estimates that more than 230 million individuals will work with AR and VR technologies by 2030.

The information systems (IS) discipline has a long-standing tradition of "envisioning how information technology will change the way we work" (vom Brocke et al. 2018, p. 357) by investigating the sociotechnical interplay of humans, technologies, and tasks (Bostrom and Heinen 1977). As such, IS scholars declared the "pressing need" (Walsh and Pawlowski 2002, p. 298) to study the organizational use of immersive technologies already in 2002, but research on AR and VR has recently intensified in conjunction with the technological advancements related to mobile and wearable computing. Broadly speaking, the interdisciplinary research efforts on AR and VR technologies follow two streams. The first is concerned with user behavior, examining the relationship between technical characteristics, such as immersion, and their impact on behavioral patterns (e.g., Steffen et al. 2019). A number of studies in this stream reveal that the acceptance of AR and VR technologies poses a barrier to their diffusion due to privacy concerns related to the devices built-in cameras, sensors, and microphones along with the novelty of the hardware (Herz and Rauschnabel 2019; Masood and Egger 2019; Schein and Rauschnabel 2021). For instance, early adopters of Google's smart glasses were subject to the onlooker-effect as bystanders were afraid of being filmed (Sergeeva et al. 2017). The second research stream draws on a prescriptive perspective, developing information technology (IT) artifacts and design principles for corporate use cases. Apart from presenting VR systems to facilitate acquiring procedural knowledge (Metzger et al. 2017), these studies introduce AR-based support systems for domains, such as logistics (Berkemeier et al. 2019) and healthcare (Klinker et al. 2020).

However, several research gaps remain to be addressed by the present dissertation. First, little is known of how practitioners can overcome the technology acceptance issues outlined above. Echoing this observation, Chuah (2019, p. 247) calls for adopting "more pragmatic" approaches to investigate users' attitudes toward AR and VR technologies. Such an approach constitutes the notion of user preferences, which allows researchers to uncover individuals' attitudes toward specific characteristics of an IT artifact in order to gather user requirements for the design of IS (Naous and Legner 2021). Second, design knowledge for other use cases of AR and VR technologies, such as virtual collaboration, is scarcely documented in IS research (e.g., Wohlgenannt et al. 2020). Moreover, immersive technologies are expected to share synergies with technologies from the realm of artificial intelligence (AI), such as conversational agents (CAs; Torro et al. 2021), but guidance for their amalgamation remains elusive. As organizational demand for AR and VR is steadily growing while industry surveys reveal that a lack of accessible software offerings impedes broader adoption in enterprises (Perkins Coie 2021), more research is needed to understand how IT providers can overcome technology acceptance issues and develop solutions suitable for the workplace. Responding to this need, this dissertation investigates user preferences and derives design knowledge for AR and VR systems to advance understanding of how they can be successfully employed in the future of work.

1.2 Research Objectives and Structure

According to Hevner et al. (2004), design science research contributes to filling the design knowledge research gap outlined in the previous section by developing IT artifacts and prescriptive knowledge to solve real-world problems. At the same time, design science research enhances understanding of how these artifacts impact human and organizational behavior by evaluating these artifacts. For this purpose, it draws on and extends a knowledge base that contains both descriptive and prescriptive knowledge (Gregor and

Hevner 2013). Taking this perspective, the overarching purpose of this cumulative dissertation is to investigate the design, application, and impact of AR and VR systems in the workplace. The aim is to provide descriptive insights into user preferences to inform design and implementation processes, to derive models, IT artifacts, and design principles (i.e., prescriptive statements for the design of IS; cf. Gregor et al. 2020), and to explore the implications of using these artifacts. Due to the high practical relevance of the subject, this dissertation not only benefits the research community but also synthesizes recommendations and implications for business consultants, decision makers in organizations, IT providers, and system developers. These insights contribute to the ongoing debate about the future of work by elaborating on novel application scenarios of AR and VR technologies (vom Brocke et al. 2018). To address this overarching objective in a comprehensive manner, this dissertation poses three research questions:

1. What are users' preferences for AR and VR systems?
2. How should AR and VR systems for the workplace be designed?
3. How can AR and VR technologies be transformed into economic value?

To establish a sound understanding of the soft- and hardware attributes and characteristics that affect user acceptance, this dissertation elicits user preferences for AR and VR systems. Building thereon, this dissertation strives to identify real-world use cases for AR and VR technologies, derive design principles, and instantiate these principles in terms of IT artifacts (i.e., AR and VR systems). To understand how the market actors associated with these technologies transform such artifacts into market offerings to create economic value, the final objective is developing a model of the AR and VR business ecosystem.

Due to the dynamic nature of the evolving field of immersive technologies, this dissertation employs a mixed-methods approach that combines a thorough selection of quantitative and qualitative research (Venkatesh et al. 2013). The research questions are divided into sub-questions and answered by the eight research contributions included in this dissertation. These contributions comprise studies from the IS research fields of technology adoption, human-computer interaction, and business model research and principally originate from the interdisciplinary research training group "Vertrauen und Akzeptanz in erweiterten und virtuellen Arbeitswelten," which was funded by the University of Osnabrück.

The remainder of this dissertation is structured as follows: Chapter 2 presents the research design, including the selected contributions, an overview of the applied methods, and the framework of the contributions. Chapter 3 synthesizes the research findings. Section 3.1 describes user preferences for AR and VR systems, Section 3.2 illustrates four artifacts intended to support work, and Section 3.3 presents an e^3-value model of the AR and VR business ecosystem. Chapter 4 provides a discussion of the findings, synthesizes implications for research and practice, and elaborates on the limitations. The dissertation ends with a conclusion and an outlook for future research.

2 Research Design

2.1 Selection of the Research Contributions

In total, this cumulative dissertation contains eight research contributions. Table 1 lists the individual contributions A–H with their identifier (ID), including their bibliographic information and rankings based on the JOURQUAL 3 ranking list provided by the Verband der Hochschullehrer für Betriebswirtschaft e.V. (VHB 2015) and the Wissenschaftliche Kommission Wirtschaftsinformatik (WKWI; Heinzl et al. 2008).

ID	Reference	Title (Translation)	Medium	Outlet	Ranking	
					VHB	WKWI
A	**Schuir**, Pöhler, Teuteberg (2022)[1]	Among price hunters, privacy advocates and tech enthusiasts: Segmentation of the virtual reality market on the example of Oculus	Journal	HMD – Praxis der Wirtschaftsinformatik	D	B
B	**Schuir**, Teuteberg (2021)	Understanding augmented reality adoption trade-offs in production environments from the perspective of future employees	Journal	Information Systems and e-Business Management	C	B
C	Vogel, **Schuir**, Thomas, Teuteberg (2020)[2]	Design and Evaluation of a Virtual Reality Application to Support Prototyping within Design Thinking Processes*	Journal	HMD – Praxis der Wirtschaftsinformatik	D	B
D	Vogel, **Schuir**, Koßmann, Thomas, Teuteberg, Hamborg (2021)[3]	Let's Do Design Thinking Virtually: Design and Evaluation of a Virtual Reality Application for Collaborative Prototyping	Confer-ence	European Conference on Information Systems (ECIS)	B	A
E	Pöhler, **Schuir**, Meier, Teuteberg (2021)[4]	Let's Get Immersive! How Virtual Reality Can Encourage User Engagement in Process Modeling	Confer-ence	International Confer-ence on Information Systems (ICIS)	A	A
F	**Schuir**, Brinkhege, Anton, Oesterreich, Meier, Teuteberg (2021)[5]	Augmenting Humans in the Loop: Towards an Augmented Reality Object Labeling Application for Crowdsourcing Communities	Confer-ence	16. Internationale Tagung Wirtschaftsinformatik	C	A
G	**Schuir**, Anton, Eleks, Teuteberg (2022)[6]	Tell me and I Forget, Show me and I Remem-ber: Design and Evaluation of a Multimodal Conversational Agent for Supporting Distance Learning	Confer-ence	17. Internationale Tagung Wirtschaftsinformatik	C	A
H	**Schuir**, Vogel, Teuteberg, Thomas (2020)[2]	Understanding the Augmented and Virtual Reality Business Ecosystem: An e^3-value Approach	Confer-ence	Lecture Notes in Business Information Processing	C	-

[1] Mr. Ludger Pöhler and the author of this dissertation worked equally on the contribution.
[2] Mr. Jannis Vogel and the author of this dissertation worked equally on the contribution. Prof. Dr. Oliver Thomas reflected critically on the methodological orientation and provided valuable feedback.
[3] Mr. Jannis Vogel and the author of this dissertation worked equally on the contribution. Ms. Cosima Koßmann made a noteworthy contribution to the questionnaire design for the final evaluation cycle. Prof. Dr. Oliver Thomas and Apl. Prof. Dr. Kai-Christoph Hamborg reflected critically on the methodological orientation.
[4] Mr. Ludger Pöhler and the author of this dissertation worked equally on the contribution. Mr. Pascal Meier reflected critically on the methodological orientation and provided valuable feedback.
[5] The author of this dissertation developed the idea for the article, was responsible for the literature review and market analysis, developed the design knowledge, and analyzed the evaluation results. Mr. René Brinkhege implemented the system and executed the evaluation. Mr. Eduard Anton contributed to the introduction as well as the artifact description. Mrs. Thuy Duong Oesterreich contributed to the implications. Mr. Pascal Meier reflected on the methodological orientation and provided valuable feedback.
[6] Mr. Eduard Anton and the author of this dissertation worked equally on the contribution. Mr. Marian Eleks implemented the concept.
* Contribution C was honored with the Best Paper Award of the year 2020.

Table 1. Overview of the research contributions

Each of the eight contributions underwent a multistage, double-blind peer review process to ensure scientific quality and was published at renowned international conferences or in reputable scholarly journals. This dissertation thus contains five conference papers and three journal articles. Due to the international research community surrounding AR and VR technologies, six contributions were written in English to increase visibility. The editorial board of the HMD Praxis der Wirtschaftsinformatik journal honored Contribution C with the 2020 Best Paper Award. Furthermore, Contributions D and E constitute the first design science research projects to present instantiated VR artifacts at the most prestigious IS research conferences (i.e., ECIS and ICIS; cf. VHB 2015).

The author of this dissertation contributed the central part of the work as the primary author for five of the research contributions (A, B, and F–H). Furthermore, he was co-author of the remaining three contributions (C–E). Prof. Dr. Frank Teuteberg reflected critically on the research design and the findings of each contribution and ensured the scientific quality by providing constructive and valuable feedback. Table 1 specifies the contributions of the articles' other co-authors.

Apart from the contributions listed in Table 1, the author of this dissertation has co-authored another 10 contributions (three journal articles, five conference articles, and two book chapters) that fall beyond the scope of this dissertation.

2.2 Spectrum of Methods

Located at the interface of computer science, engineering, management, and psychology, IS research strives to understand "the development, use, and application of information systems by individuals, organizations, and society" (Baskerville and Myers 2002, p. 11). At the macro level, IS research comprises two distinct but composite paradigms: design science and behavioral science (Hevner et al. 2004). The design science paradigm involves developing and evaluating new artifacts (i.e., constructs, instantiations, methods, and models) and design knowledge to solve real-world problems (Hevner et al. 2004). In contrast, the behavioral science paradigm describes real-world phenomena (e.g., technology acceptance), for instance, by developing and verifying theories that predict human behavior (Hevner et al. 2004). This cumulative dissertation predominantly follows the design science paradigm by developing instantiations (i.e., IT artifacts) and models along with abstracted design knowledge (i.e., design principles; Gregor et al. 2020).

Hevner (2007) proposes three cycles to portray the design science research paradigm: the relevance cycle, the rigor cycle, and the design cycle (cf., Figure 1). The relevance cycle initiates a design science research project by revealing a research problem to be solved. As such, it ensures the consideration of an artifact's application domain through requirements elicitation and field-testing activities related to people, organizations, and technologies. The rigor cycle maintains the scientific rigor of design science research project by drawing on and extending theoretical and methodological foundations from the prevailing knowledge base, for instance, by integrating existing design principles, observations, and research methods. The design cycle constitutes the "heart of a design science research project" (Hevner 2007, p. 90) and includes the iterative design and evaluation of artifacts.

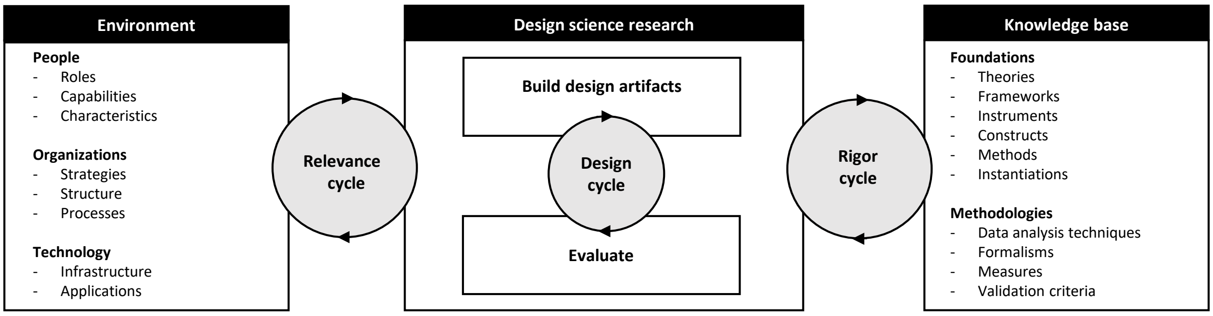


Figure 1. Operationalization of design science research based on Hevner (2007)

Six of the contributions in this cumulative dissertation (i.e., C–H) include the development and evaluation of specific artifacts in line with the design science research paradigm, while two contributions (i.e., A and B) include a behavioral perspective that inform the design of IT artifacts by revealing user preferences (Naous and Legner 2021).

To follow the above-mentioned paradigms, the IS discipline employs a wide range of research methods, each with specific advantages and disadvantages (Wilde and Hess 2007). The body of knowledge distinguishes between qualitative and quantitative methods. Qualitative research methods rely on collecting, processing, and interpreting non-numerical (i.e., qualitative) data (e.g., interview transcripts, observations) and are suitable for exploratory research (e.g., to discover new phenomena; Recker 2012; Schultze and Avital 2011). Conversely, quantitative research methods primarily draw on numerical (i.e., quantitative) datasets (e.g., survey results) and serve to empirically confirm or contradict hypothesized cause-and-effect relationships through statistical inferences or numerical benchmarks (Recker 2012). This cumulative dissertation follows a mixed-methods approach by combining multiple qualitative and quantitative research methods (Venkatesh et al. 2013). Table 1 summarizes the methods applied in the individual contributions and contains references to sound specifications of the methods.

Research Method	Contribution								Reference(s)
Qualitative Research	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	
e^3-value modeling								•	Gordijn and Akkermans (2001)
Content analysis	•	•			•		•	•	Mayring (2000)
Interviews	•	•			•		•	•	Myers and Newman (2007)
Focus group				•	•	•	•		Morgan (1998)
Prototyping			•	•	•	•	•		Hevner et al. (2004)
Literature review	•	•	•	•	•	•	•	•	vom Brocke et al. (2009); Webster and Watson (2002)
Quantitative Research									
Conjoint analysis	•	•							Green and Srinivasan (1978)
Cluster analysis	•	•							Ward (1963); Hair et al. (2009)
Lab/field experiment			•	•	•	•			Palvia et al. (2004)
Survey	•	•	•	•		•			Recker (2012)

Table 2. Research methods employed in this dissertation

As shown in Table 2, each contribution builds on an initial literature review following the guidelines proposed by vom Brocke et al. (2009) to explore prevailing work and research gaps in the investigated field. This dissertation predominantly employs qualitative research methods to inform the design processes and obtain feedback on the artifacts as AR and VR technologies are subject to dynamic developments that require qualitative exploration. Conversely, the quantitative research methods obtain empirical insights into user perceptions of immersive technologies. Apart from the methods listed in Table 2, the author of the dissertation employed several contemporary project management and problem-solving approaches (e.g., Scrum [Schwaber and Sutherland 2011] and design thinking [Uebernickel et al. 2015]) along with heuristic evaluation techniques from the field of human-computer interaction research (e.g., cognitive walkthroughs [Wharton et al. 1994]). Although these techniques are not stand-alone inquiry methods, they contributed to the design science research projects (cf. Vogel et al. 2021).

2.3 Framework of the Research Contributions

According to Gregor and Hevner (2013), design science research consumes and produces two distinct types of knowledge: descriptive and prescriptive. Descriptive knowledge encompasses observations of real-world phenomena (e.g., hypotheses, theories, and patterns), while prescriptive knowledge includes operational guidance for designing artifacts (e.g., design principles and design theories) along with the artifacts themselves (e.g., constructs, instantiations, methods, and models). Design science research primarily produces prescriptive knowledge but employs descriptive and prescriptive knowledge to justify research problems and design considerations (Gregor and Hevner 2013).

Informed by Gregor and Hevner's (2013) framework for the roles of knowledge in design science research, this dissertation combines descriptive and prescriptive knowledge to solve real-world problems in four application environments (cf. Figure 2).

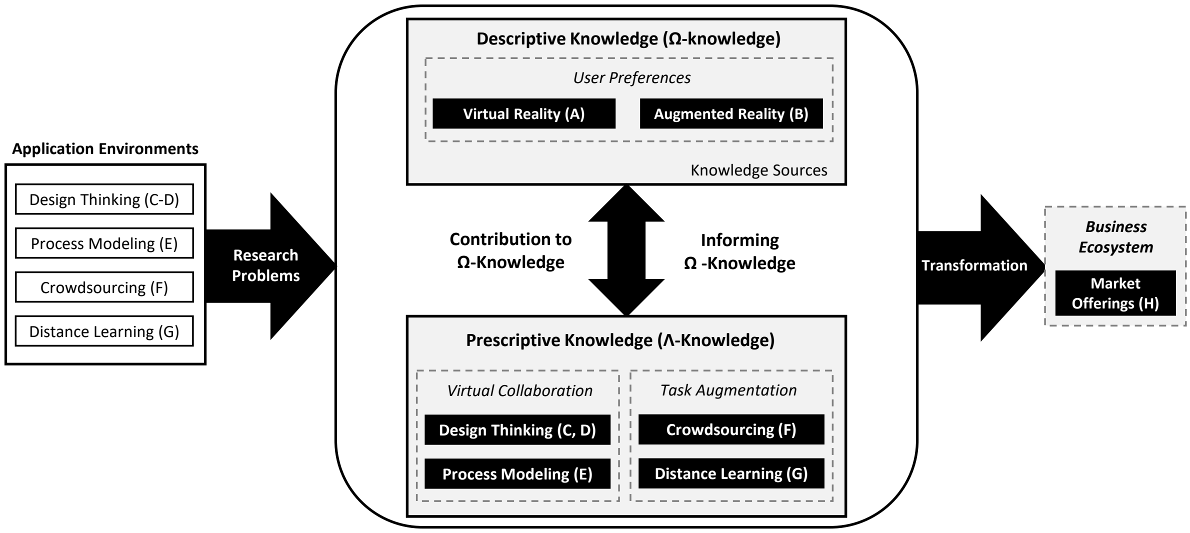


Figure 2. Classification of the contributions adapted from Gregor and Hevner (2013)

As shown on the left side of Figure 2, this dissertation resolves problems occurring within collaborative practices, including design thinking and process modeling (Brown 2008; Dean et al. 1994), by deriving virtual collaboration solutions. Furthermore, it aims to solve problems associated with crowdsourcing and distance learning by developing task augmentation solutions (Alea et al. 2020; Blohm et al. 2013). To further establish a foundation for future design science projects by revealing user preferences, and to understand the viability of these artifacts, this dissertation employs three pillars.

The first pillar synthesizes descriptive knowledge based on user preferences for AR and VR systems. Traditionally, IS research has employed adoption theories such as the technology acceptance model (TAM; Davis 1989) to explain individual attitudes toward IS (Benbasat and Barki 2007). However, as Lee et al. (2003, p. 766) state, “TAM’s narrow focus [on perceived usefulness and perceived ease of use has] reduced attention on the role of technology and design” in IS research. Contributions A and B apply conjoint analyses to obtain a more contextual perspective on user attitudes. This measurement method enables researchers to decompose the overall utility of an IT artifact by revealing the relative importance values of their attributes and part-worth utilities of the attributes’ levels (Naous and Legner 2021). Contribution A takes a more hardware-related perspective and examines VR headset preferences (Schuir et al. 2022a), while Contribution B explores preferences for software tailored to AR assistance systems, considering the example of service support in production environments (Schuir and Teuteberg 2021).

The second pillar synthesizes prescriptive knowledge for designing AR and VR systems, including solutions to support virtual collaboration via VR and facilitate tasks via AR. To support virtual collaboration via VR, Contributions C and D present a design science research project resolving issues associated with design thinking prototyping practices by leveraging the rich visualization and communication capabilities of VR. The artifact enables researchers and practitioners to develop new products, services, and business processes (Vogel et al. 2020; Vogel et al. 2021). The successful reengineering of business processes, in turn, requires a human-centric approach to ensure acceptance by all process stakeholders (Grover et al. 1995). Contribution E presents a multiuser VR application supporting collaborative process modeling in virtual replicas of work environments (Pöhler et al. 2021). Conversely, the remaining two projects combine AR and AI technologies (i.e., computer vision, and CAs) to support tasks. Contribution F addresses the crowdsourcing of micro-tasks in human-in-the-loop processes, where individuals label objects in image datasets to train supervised AI classifiers (Fang et al. 2017). From a worker’s perspective, these tasks are monotonous, time-consuming, and costly to the organization. To streamline this process, the contribution presents an AR application that enables users to gather structured image datasets enabling the automated training of artificial neural networks for object detection (Schuir et al. 2021). Due to its rich visualization capabilities, another promising AR application scenario is learning (Ma et al. 2016). Contribution G orchestrates these capabilities of AR and voice-based interaction of CAs to support students in distance learning (Schuir et al. 2022b).

Together, the four artifacts can be transformed into new products and services for the workplace. Technology-driven market offerings typically arise in business ecosystems where organizations surround technical innovations, such as AR and VR, to develop new value propositions (Moore 1993). The third pillar of this dissertation (Contribution H) presents a model that abstracts the actors and value streams within the AR and VR business ecosystem based on the e^3-value ontology to illustrate the technologies’ value creation mechanisms (Gordijn 2004, Schuir et al. 2020).

3 Synthesis of the Research Contributions

3.1 User Preferences

According to McFadden (1986), user preferences are among the main predictors of behavioral intention to choose products or services. A conjoint analysis constitutes an unobtrusive instrument for collecting user preferences for IS or IT by simulating real choices (Naous and Legner 2021). Thus, to answer the first research question, this section illuminates user preferences for AR and VR systems based on two conjoint analyses examining two exemplary application scenarios. Both studies employ hierarchical Bayes random-effects models and Markov chain Monte Carlo algorithms to obtain individual part-worth coefficients and leverage two-stage cluster analyses by combining Ward's (1963) method with K-means (Hair et al. 2010) to identify groups with similar preferences.

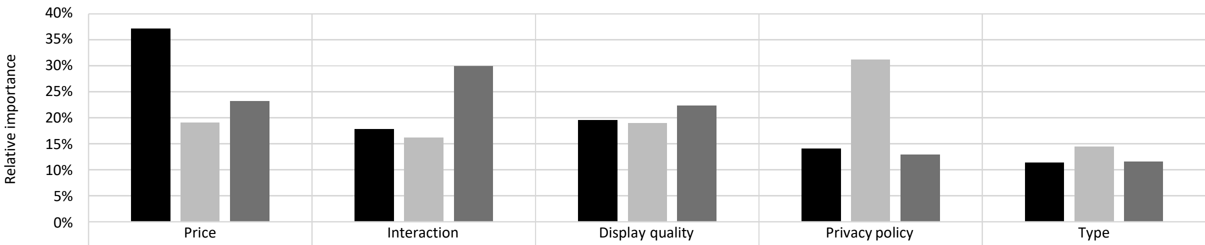
With the advances in wearable computing, VR headsets have become a mass-market product. Specifically, the coronavirus disease 2019 (COVID-19) pandemic has fueled enterprises and individuals' demands for productivity-focused VR (e.g., learning; Ball et al. 2021; Perkins Coie 2021). Despite growing sales figures, manufacturers struggle with "defining and developing the design elements of VR hardware" (Manis and Choi 2019). For instance, in 2020, Oculus dominated the market for head-mounted displays, shipping more than one million units in the second quarter, while its closest competitor, Sony, sold only 125,000 units (Statista 2021). However, Oculus was subjected to serious criticism due to its privacy policy, which required users to have an active Facebook account to use its products (Oculus 2021). In Germany, this development led to a halt in selling the Quest 2 due to a legal dispute with the German Federal Cartel Office (2021). To obtain empirical insights into how users perceive these challenges and identify vital design elements of VR devices, Contribution A reveals user preferences for VR headsets based on a survey with 225 respondents. Table 3 summarizes the averaged preferences.

Attribute	Level	Part-Worth Utility	Relative Importance
Price	€400	3.750	28.01%
	€650	0.771	
	€900	−4.521	
Interaction	Controllers	−3.342	21.29%
	Controllers with finger tracking	0.286	
	Hand tracking	3.057	
Display quality	Low	−2.021	20.47%
	Medium	−1.449	
	High	3.470	
Privacy policy	Facebook login	−2.093	17.54%
	Oculus login	−0.534	
	Customizable	2.627	
Type	Tethered	−0.792	12.05%
	Standalone	0.792	
Note: averaged preferences were not discussed in Contribution A, but are provided in its appendix.			

Table 3. Preferences for VR headsets based on Schuir et al. (2022a)

Based on the part-worth utilities, users prefer low-priced stand-alone VR headsets supporting hand tracking and featuring high display resolutions. Furthermore, users seek customizable privacy configurations to avoid sharing sensitive sensor, camera, and microphone data with third parties (i.e., VR manufacturers). Thus, when implementing VR, organizational decision-makers are encouraged to select products with this configuration to accommodate user needs. Moreover, the results highlight price (28.01%) as the most important attribute, indicating high price sensitivity. Interaction (21.29%) and display quality (20.47%) constitute the second and third most important attributes. It is thus imperative that IT providers and decision-makers particularly focus on display characteristics and interaction modalities when developing and selecting VR headsets.

A complementary cluster analysis reveals that these preferences are inhomogeneous and identifies three clusters: price chasers (Cluster 1, 40.89% of the sample), privacy advocates (Cluster 2, 22.22% of the sample), and technology enthusiasts (Cluster 3, 36.89% of the sample). Figure 3 visualizes the relative importance values per cluster.



	Price	Interaction	Display quality	Privacy policy	Type
Cluster 1	37.16%	17.88%	19.55%	14.06%	11.35%
Cluster 2	19.10%	16.20%	19.02%	31.24%	14.44%
Cluster 3	23.25%	29.94%	22.35%	12.91%	11.55%

Figure 3. Relative importance values for VR headsets per cluster based on Schuir et al. (2022a)

Although the clusters prefer the same product configurations on average, the attribute valuations differ significantly. Members of Cluster 1 seek low-priced VR headsets with high display quality. The privacy policy is more than twice as important to members of Cluster 2 as those in the other clusters, while members of Cluster 3 display a strong orientation toward interaction and display quality. Acknowledging these clusters can help IT providers devise marketing and communication strategies targeting the customer segments and thus support VR diffusion among individuals and organizations. Developers, researchers, and organizational decision-makers can leverage these preferences when designing and implementing VR systems (Schuir et al. 2022a).

As stated in the introduction, AR technology providers also face user-level hurdles (Schein and Rauschnabel 2021). Specifically, as AR systems “must keep track of what the operator is doing and seeing” (Syberfeldt et al. 2016, p. 113), behavioral data-processing policies require careful attention. Moreover, the narrow field of view of AR smart glasses increases the risk of occupational accidents (Malý et al. 2016). Based on the example of head-worn AR implementation in production environments, Contribution B examines the relative importance values of four AR user assistance systems’ attributes and integrates financial incentives to determine the calculus required to compensate for violating user privacy through employee surveillance measures. The findings are based on a survey of 179 future workers. Table 4 summarizes the averaged results.

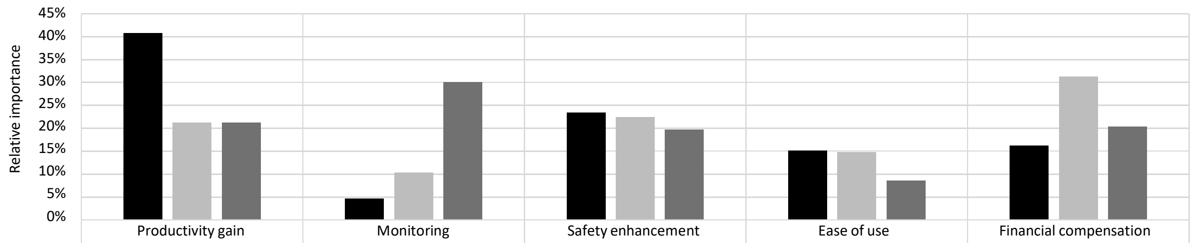
Attribute	Levels	Part-Worth Utilities	Relative Importance
Productivity gain	No increase	−2.076	27.40%
	Low gain	−0.532	
	High gain	2.608	
Financial compensation	€0/month	−2.134	23.15%
	€100/month	0.311	
	€200/month	1.823	
Safety enhancement	No safety enhancement	−1.898	22.21%
	Presence of safety enhancement	1.898	
Performance monitoring	Transparent	−1.211	14.48%
	Anonymous	−0.052	
	None	1.263	
Ease of use	Complex to use	−1.091	12.77%
	Easy to use	1.091	

Table 4. Preferences for AR systems (Schuir and Teuteberg 2021)

As shown in Table 4, functional benefits (i.e., productivity gains and safety enhancement), along with the financial compensation are the main drivers for the adoption of AR systems in the present scenario, while monitoring (14.48%) and ease of use (12.77%) play a subordinate role. This finding partly contradicts the TAM, which frames perceived usefulness and ease of use as primary antecedents of behavioral intention towards using technologies (Davis 1989). Instead, safety-enhancing features and privacy concerns are slightly more important than ease of use in the context of AR. Thus, a calculation of the monetary equivalents to compensate the utility losses induced by employee monitoring, as patented by Amazon (Bernal 2018), amounts to between €100 to €160 (Schuir and Teuteberg 2021). Given that extant research (e.g., Jacobs et al. 2019) discusses the implementation of financial incentives to promote the adoption of AR among workers, organizations are encouraged to carefully select use cases to ensure acceptance while avoiding additional costs (e.g., incentives) for the implementation of AR, for instance, by providing context-sensitive process guidance to inexperienced workers (Schuir and Teuteberg 2021).

In line with Contribution A, Contribution B evinces that individual preferences differ significantly, resulting in three different clusters: strivers (Cluster 1, 30.39% of the sample), payroll hunters (Cluster 2, 33.82% of the sample), and privacy keepers (Cluster 3, 35.78% of the sample). Figure 4 visualizes the relative importance values per cluster.

Members of Cluster 1 intend to use AR systems if they lead to functional benefits such as productivity gains and safety enhancement. Conversely, the monitoring attribute only slightly impacts choices for this cluster. Similarly, Cluster 2 members intend to use AR systems generating high productivity gains and increasing occupational safety but weigh these attributes significantly lower than Cluster 1 due to their desire to maximize financial incentives. Meanwhile, individuals within Cluster 3 seek AR systems with a high privacy level. With a relative importance of 30.08%, Cluster 3 attributes significantly more importance to monitoring than Clusters 1 or 2. Latent constructs can explain the divergence between the clusters. Cluster 1 exhibits the highest index values for attitudes toward using AR and the lowest values for perceived privacy concerns, whereas Cluster 3 is more critical toward AR due to privacy concerns and a low level of legal trust.



	Productivity gain	Monitoring	Safety enhancement	Ease of use	Financial compensation
Cluster 1	40.72%	4.58%	23.42%	15.10%	16.18%
Cluster 2	21.28%	10.27%	22.46%	14.74%	31.25%
Cluster 3	21.30%	30.08%	19.62%	8.60%	20.40%

Figure 4. Relative importance values for AR systems per cluster (Schuir and Teuteberg 2021)

Together, these findings answer the first research question of this cumulative dissertation by revealing user preferences for AR and VR systems. Moreover, they inform technology providers, organizational decision-makers, and researchers, allowing them to a) tailor their products and services to meet user needs, b) prioritize user requirements, and c) devise communication strategies to launch VR and AR in a user-centric manner.

3.2 Design Principles and Instantiations

This section presents four design science research projects to answer this dissertation's second research question. Two of these artifacts leverage the immersive, interactive, and manipulative characteristics of VR to support virtual collaboration, focusing on design thinking and process modeling (cf. Section 3.2.1). The remaining two artifacts employ the capabilities of AR to support by augmenting workers in the crowdsourcing context and students in distance learning settings (cf. Section 3.2.2). Each project followed the problem-centered design science research methodology proposed by Peffers et al. (2007) and employed an initial literature review to identify issues in the investigated domains. Subsequently, meta-requirements and design principles were derived based on empirical findings and focus group discussions. As the IT artifacts are embedded in sociotechnical systems, each project followed a human risk and effectiveness evaluation strategy in accordance with the framework for design science research evaluation proposed by Venable et al. (2016). Accordingly, the early evaluations employed artificial and formative evaluations to validate the usefulness of the design knowledge based on a proof-of-concept. Based on the feedback, the artifacts underwent several refinements before proceeding to more natural evaluations.

3.2.1 Virtual Collaboration

Collaboration refers to an activity "in which two or more agents (individuals or organizations) share resources and skills to solve problems so that they can jointly achieve one or more goals" (Boughzala and De Vreede 2015, p. 133). The advent of the COVID-19 pandemic has fueled an increasing demand for solutions to virtual collaboration (Hofmann et al. 2020). Simultaneously, it triggered the need to synthesize rapid responses to unforeseen events based on new products, services, and processes through collaborative problem-solving approaches.

Design thinking: One frequently applied approach for collaborative problem solving is design thinking (Brown 2008). However, infrastructural challenges, such as geographical distribution, along with a lack of design skills among interdisciplinary design thinking teams constrain design thinking prototyping practices (Carlgren et al. 2016). Due to these issues, Contributions C and D present an immersive creativity support system that leverages VR-specific affordances (e.g., immersion, co-presence, and media richness; Alahuhta et al. 2014) to support collaborative prototyping within design thinking processes. Thereby, Contribution C presents an initial proof-of-concept that evolved through three iterations and is presented in Contribution D. Guided by the theory of organizational creativity proposed by Woodman et al. (1993), the final artifact provides a) appropriate communication channels, b) a three-dimensional prototyping space, and c) prototyping tools. Figure 5 summarizes the issues, meta-requirements, and design principles.

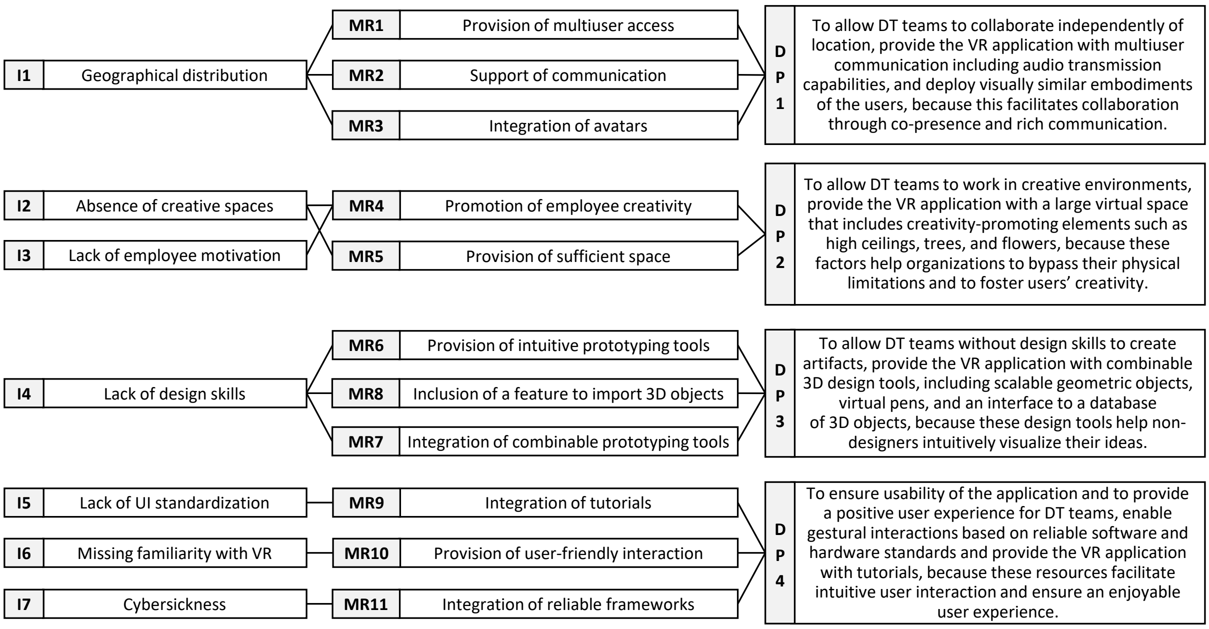


Figure 5. Derivation of design principles for collaborative prototyping based on Vogel et al. (2021)

The immersive creativity support system aims to provide dispersed users with a virtual space equipped with suitable prototyping tools. To enable communication and foster a feeling of co-presence, the system depicts users as avatars and transmits their audio signals and movements in real time (cf. left, Figure 6). The room design employs supraliminal cognitive priming by integrating creativity-supporting visual elements such as warm colors and high walls (Bhagwatwar et al. 2013). The room is divided into three areas: 1) a tutorial area to familiarize users with gestural interaction, 2) an object search area to import three-dimensional (3D) objects, and 3) a shelf with geometries (cf. right, Figure 6).

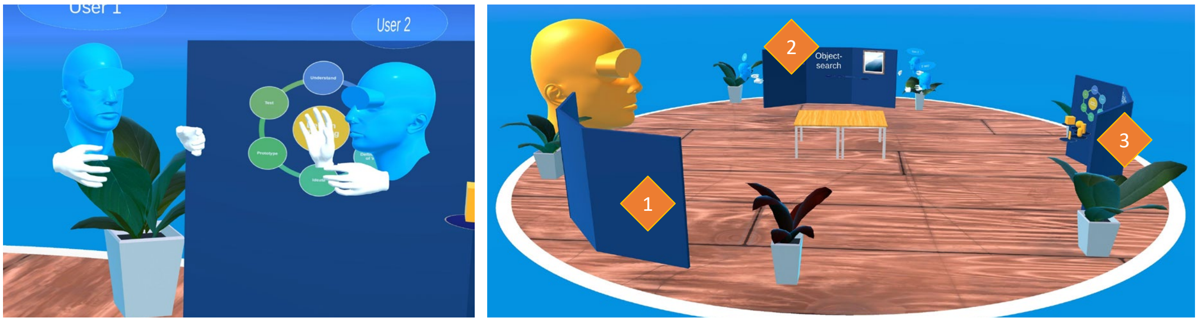


Figure 6. Co-presence and virtual room design based on Vogel et al. (2021)

The instantiation features three prototyping tools to support the visualization of design ideas. Consistent with the preferences revealed in Contribution A, these features can be accessed via hand tracking. First, users can grab and color predefined geometric shapes (cubes, cylinders, and spheres; cf. 5 Figure 7). Second, with the object browser, users can search and import low-resolution 3D objects (cf. 7, Figure 7). Third, the drawing mode supports sketching and annotating objects (cf. 8, Figure 7). All three features can be combined, and the hand menu allows users to color and delete the objects (cf. 9–11, Figure 7).

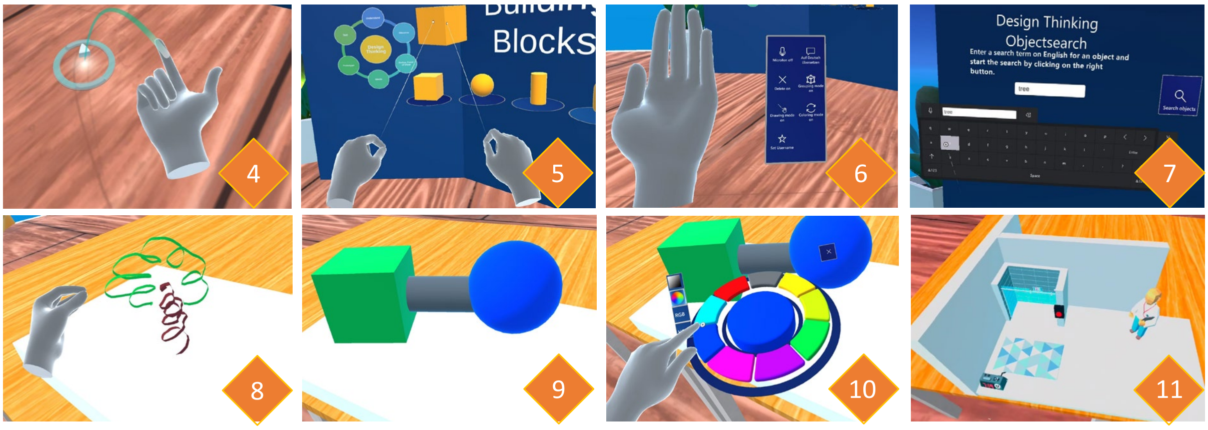
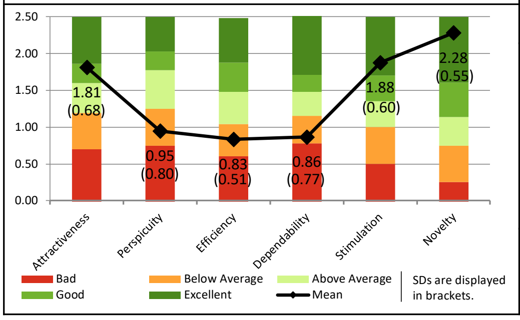


Figure 7. Overview of the prototyping tools (Vogel et al. 2021)

The final evaluation, which comprised a laboratory experiment with 24 participants, confirmed that the immersive creativity support system supports the prototype creation in geographically distributed settings. Compared to the benchmarking values provided by the User Experience Questionnaire, the application provides a stimulating, attractive, and novel user experience, although it still possesses minor weaknesses in terms of perspicuity, efficiency, and dependability (Schrepp et al. 2017). The creativity support index achieved an average of 70.79 out of a maximum of 100 points (Cherry and Latulipe 2014), surpassing prior immersive creativity support systems (Vogel et al. 2021). Moreover, the application's total Simulator Sickness Questionnaire score (31.5) was low compared to benchmarking values with modern VR headsets (Kennedy et al. 1993).

The evaluation results suggest that VR-based prototyping constitutes a promising supplement for design thinking processes by allowing virtual teams to visualize their design ideas despite being geographically dispersed. As such, the artifact might also enable workshop facilitators to complement physical workshop settings with virtual elements to enhance the hedonic quality of collaborative tasks (Vogel et al. 2021).



b) Creativity Support and Satisfaction

Dimension	Construct	AVG Score	SD
Creativity Support in accordance with Cherry & Latulpe (2014)	Collaboration	13.67	2.75
	Enjoyment	15.42	2.39
	Exploration	13.25	2.35
	Expression	14.21	3.03
	Immersion	15.13	2.08
	Results worth effort	13.29	2.77
Satisfaction in accordance with ISO 9241-940	Comfort	5.5	0.85
	Affective	6.37	0.66
	Irritability	4.54	0.82

C) SSQ Symptoms

Simulator Sickness Questionnaire in accordance with Kennedy et al. (1993)

SSQ Scores	Mean $\bar{x}$	Median $\tilde{x}$	SD $\hat{\sigma}$
Nausea (N)	13.5	9.5	17.3
Oculomotor (O)	31.9	26.5	21.7
Disorientation (D)	38.9	27.8	33.1
Total Score (TS)	31.5	26.1	21.1

Figure 8. Evaluation of VR-based prototyping (Vogel et al. 2021)

Process modeling: VR holds much promise for externalizing complex phenomena that are difficult to communicate via two-dimensional (2D) images (Alahuhta et al. 2014). An example includes business process modeling, which involves the visual abstraction of value-driven activities. Process modeling is a complex task requiring in-depth knowledge of process modeling techniques and domain expertise (Pinggera et al. 2010). To manage this complexity, process analysts typically conduct workshops with process stakeholders to gather process knowledge and translate it into process models (Rosemann et al. 2011). However, issues, such as the lack of involvement of process stakeholders along with documenting workers' tacit knowledge, pose major challenges (Schmidt and Nurcan 2008; Silva and Rosemann 2012), resulting in a gap between the process model and actual process. This gap is termed the model-reality divide (Schmidt and Nurcan 2008). To encounter these issues, Contribution E presents a VR application supporting collaborative process modeling by shifting workers from the role of the information source to that of the active process modeler, while a process analyst can support them. Figure 9 summarizes the issues, meta-requirements, and design principles resulting from four design cycles.

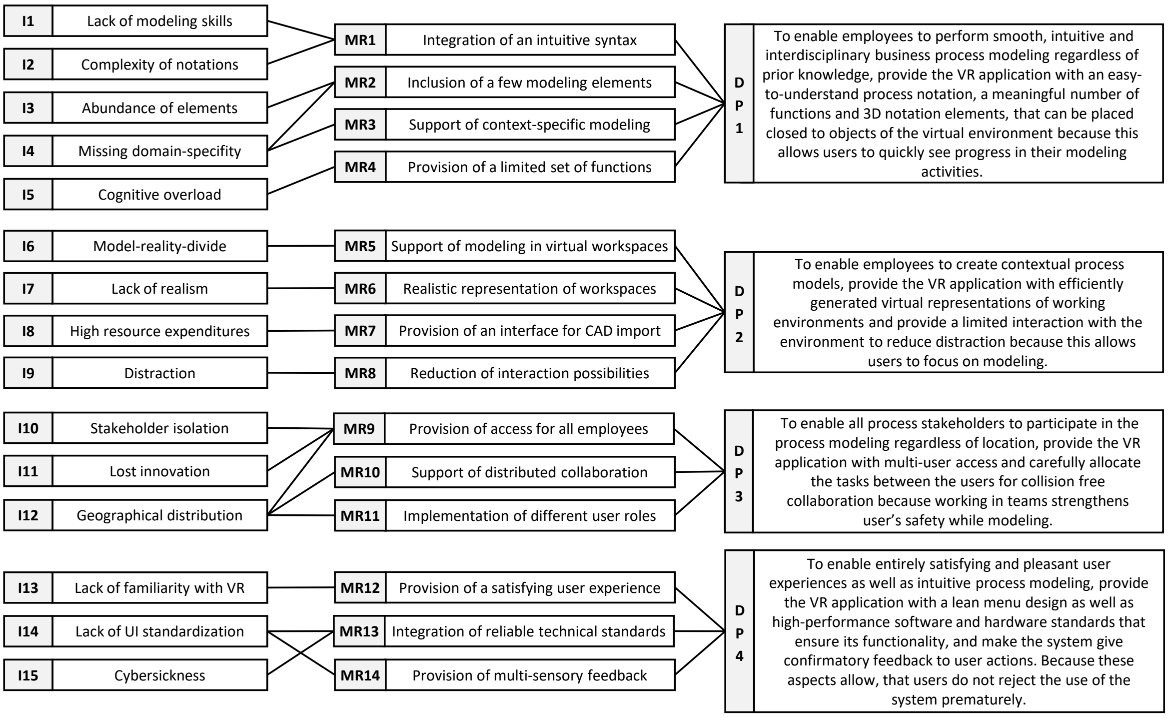


Figure 9. Derivation of design principles for process modeling based on Pöhler et al. (2021)

The instantiation of the design principles supports the documentation of business processes in virtual replicas of real work environments by enabling users to place notation elements (e.g., the "assembly" function) where they are executed (e.g., at the assembly table). For this purpose, it features an interface for importing and customizing computer-aided design models or 3D scans of work environments, such as production halls. Following the Business Process Model and Notation (BPMN) standard (Object Management Group 2021), the integrated process modeling toolkit provides functions to create, name, position, and delete activities and events (cf. 1–5, Figure 10). To indicate the order of a process and visualize decisions or alternative paths, the process modeling toolkit includes a function to connect the elements and visualize forks and joint gateways (cf. 6–9, Figure 10). The role concept, comprising a VR user and a desktop user, supports collaboration between domain and modeling experts. The VR user is responsible for placing, naming, and connecting the notation elements in the virtual environment through motion controllers while the desktop user guides the VR user during the modeling stage.

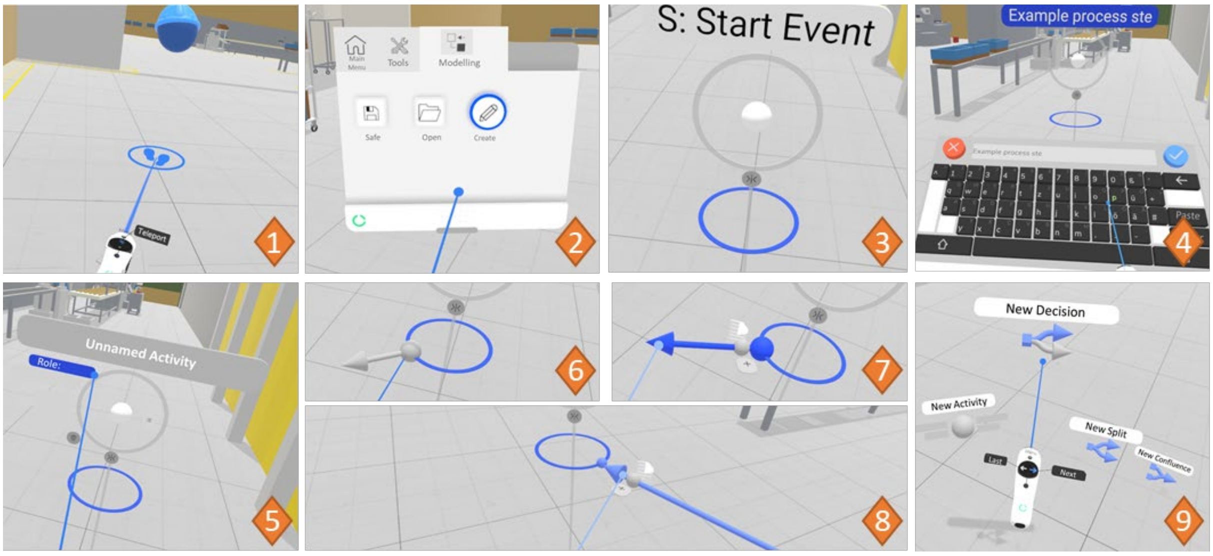


Figure 10. Overview of the process modeling application based on Pöhler et al. (2021)

The final evaluation comprised three field experiments and three focus group discussions with manufacturing, food production, and mechanical engineering firms. During the field experiments, all participants accomplished the modeling task. In the focus groups, respondents highlighted the hedonic user experience. For instance, one participant emphasized, "[i]t is more fun to work on the process than discussing it in paper form" (Pöhler et al. 2021, p. 12). Compared with the baseline scenario (i.e., 2D BPMN modeling workshops), the advantages of the VR-based approach include stronger contextualization of process models (e.g., due to spatial components), facilitated communication of processes (e.g., in onboarding scenarios), and support of business process improvement. For example, by collaboratively exploring 3D process models, process stakeholders can improve spatial arrangements (e.g., walking routes). Given these findings, the artifact could be combined with VR-based factory planning to enable organizations (e.g., manufacturing firms) to document and revise processes before implementing them (Pöhler et al. 2021).

3.2.2 Task Augmentation

While the advances in machine learning and robotics are accelerating automation of repetitive tasks, new human-machine configurations persist in the workplace. Such an example includes human-the-loop processes, where humans (e.g., data scientists) prepare data, teach, or fine-tune machine learning models (Grønsund and Aanestad 2020).

Crowdsourcing: Contribution F exemplifies the interplay between automation and humans in the loop. AI-based object detection holds huge potential to automate routine tasks but requires pre-trained machine learning models (Janiesch et al. 2019). A flexible approach to obtaining structured training data involves crowdsourcing (Gu and Leroy 2020). However, this process is time-consuming and cost-intensive as crowdworkers must label each image individually (Haq 2020). Contribution F targets improving task allocation in human-in-the-loop processes by combining an AR-based mobile application with a centralized infrastructure to provide an end-to-end process of capturing structured datasets, training convolutional neural networks (CNNs), and detecting objects.

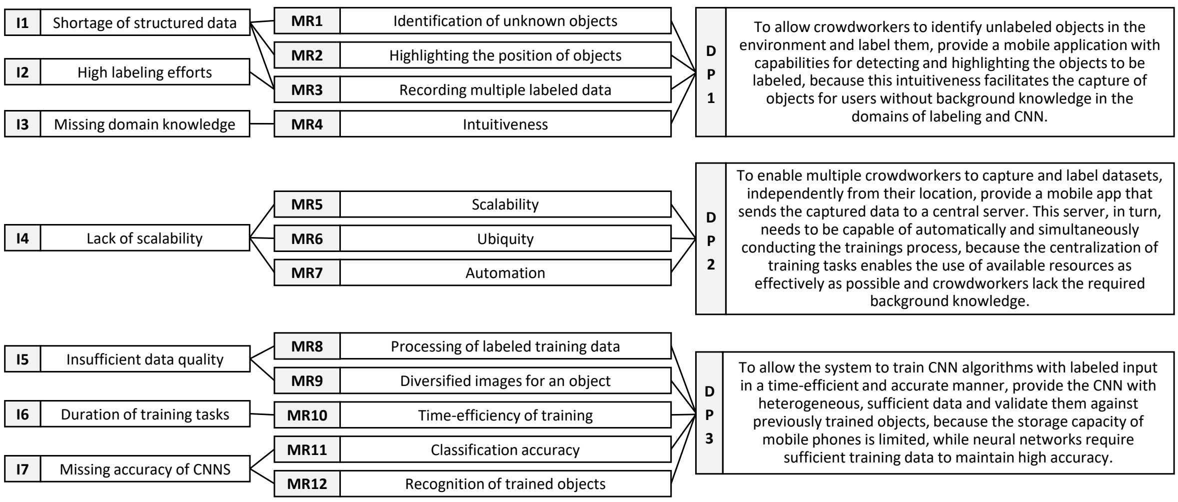


Figure 11. Derivation of design principles for object labeling based on Schuir et al. (2021)

The architecture depicted in Figure 12 contains three subsystems: 1) a user mobile application interface, 2) a file server, functioning a cache for the structured image datasets and CNN models, and 3) a training server using the TensorFlow (2021) framework.

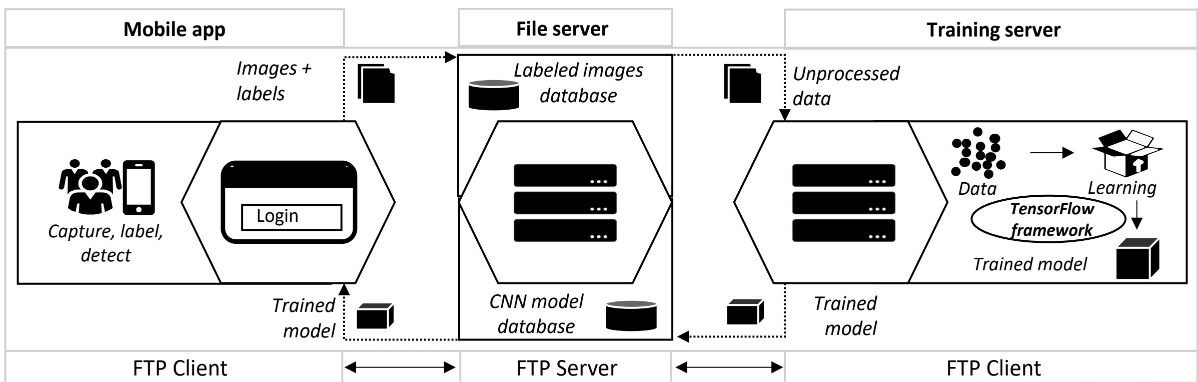


Figure 12. System architecture for AR-based labeling (Schuir et al. 2021)

Figure 13 visualizes the labeling process from a user perspective. Starting the mobile application, the user views a livestream of the smartphone camera. By holding the camera over their environment, the user can identify unknown objects and subsequently enter an object name (e.g., salt; cf. left Figure 13). Once the recording is activated, the application begins saving the images, including the objects' spatial positions. The user films the object from different perspectives to collect diversified images of it. Once 2,000 images have been captured, the user can send the dataset to the file server (cf. middle, Figure 13). On completing the training, the mobile application retrieves the trained CNN models from the file server. At this stage, the application can detect objects. If the application detects an object, it displays the object name and classification accuracy (cf. right, Figure 13).

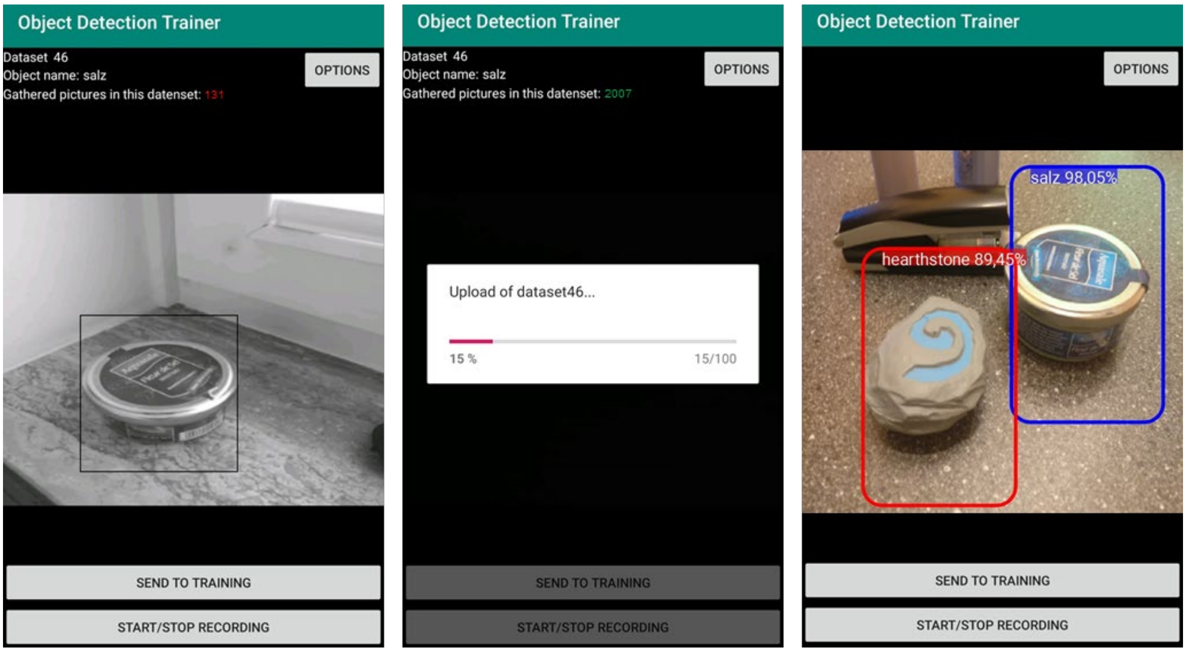


Figure 13. User interface of the mobile AR application (Schuir et al. 2021)

A train-test split with 15 previously trained models indicated that the models could detect objects with a low error rate as 1.01% of objects were not detected, and an average of 1.34% of objects were detected as false positives. Moreover, a second evaluation comprising a laboratory experiment with 15 participants demonstrated that the artifact simplifies the workflow of capturing objects, labeling them, and training CNNs. Figure 14 summarizes the findings of the User Experience Questionnaire (Schrepp et al. 2017).

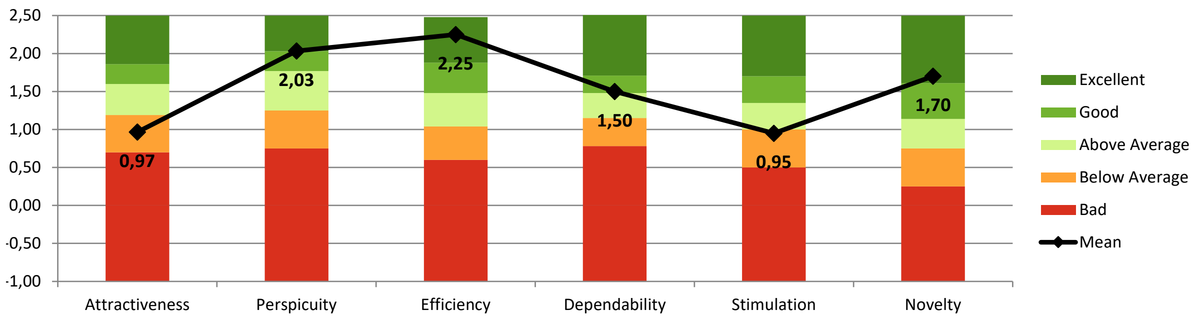


Figure 14. User experience evaluation of the mobile application (Schuir et al. 2021)

Based on the findings, AR-based labeling constitutes a promising alternative to manually labeling predefined image datasets to gather structured data for training supervised AI classifiers for high-level object detection tasks. As such, the architecture and design principles may inform crowdsourcing platforms such as Amazon Mechanical Turk to enable them to streamline labeling tasks and support AI diffusion (Schuir et al. 2021).

Distance learning: While AI-based technologies mainly require human intervention before accurately recognizing patterns or detecting objects (Grønsund and Aanestad 2020), they can also assist humans, for instance, by augmenting learning processes. Intelligent systems, such as CAs, enable text- or speech-based human-machine interactions to provide learners with individual support by leveraging natural language-processing techniques (Kerry et al. 2008). Despite their promising capabilities, the visual output of most extant pedagogical CAs remains limited to their embodiments as avatars (Weber et al. 2021). However, the COVID-19 pandemic and associated shift to distance learning have necessitated supporting remote learners in self-directed learning scenarios by providing enriched illustrations, which are difficult to display on 2D screens. Simultaneously, geographical distribution has impeded communication between teachers and learners, causing problems for both parties (e.g., regarding follow-up questions from the students; Schuir et al. 2022b).

Considering the example of school-based education, Contribution G presents a multimodal CA that augments self-directed learning by providing 3D visualizations via AR and verbal explanations via voice output. Based on seven issues surrounding distance learning, 11 meta-requirements were translated into three design principles (cf. Figure 15).

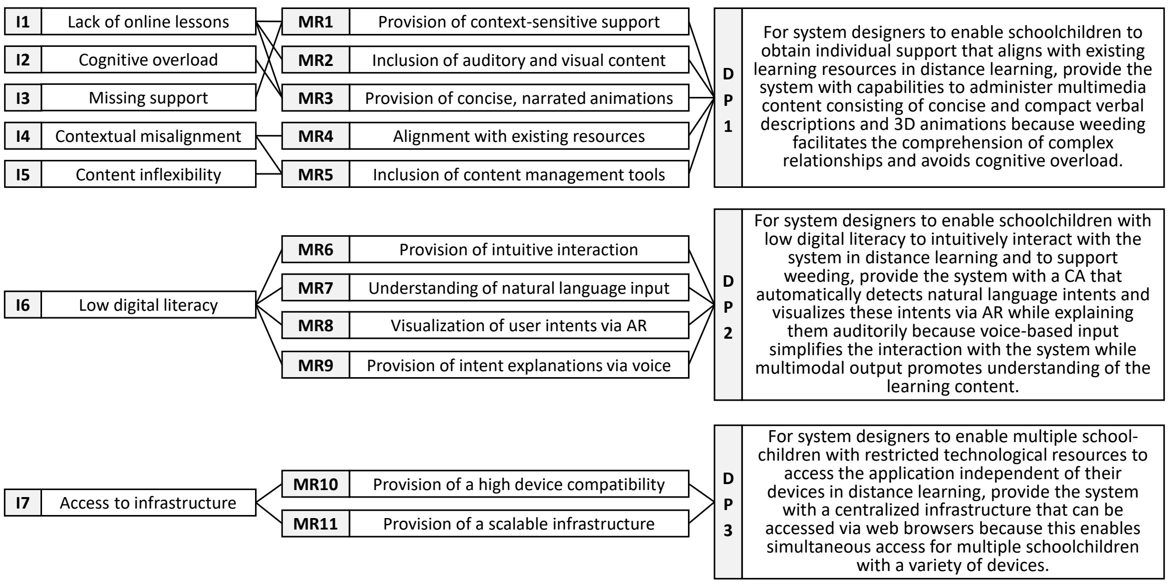


Figure 15. Derivation of design principles for multimodal CAs based on Schuir et al. (2022b)

Rooted in Mayer's (2005) cognitive theory of multimedia learning, the concept incorporates a cognitive load-reducing multimedia learning principle known as weeding. The weeding principle suggests combining brief verbal explanations with interactive visualizations to explain phenomena and purposefully draw the learner's attention toward the multimedia content without oversaturating the cognitive system (Mayer and Moreno

2003). The artifact's purpose is twofold. On the one hand, it is intended to support learners in a context-sensitive fashion by applying the weeding principle. On the other hand, it is intended to relieve teachers by automatically answering questions that frequently occur during classes. Thus, learners can ask the AR-based CA follow-up questions concerning comprehension difficulties (e.g., reading textual learning resources). The multimodal CA answers by verbally explaining and visualizing the information. Here, it identifies learners' intents and returns content teachers can administer beforehand. The concept integrates a web portal for content administration to allow teachers to tailor the content provided by the CA to their target audience (e.g., students, and trainees) and the specific context (e.g., vocational training or schools). Teachers can manage 3D models, verbal descriptions, and keywords (i.e., intents) when preparing a lesson with this content administration. Figure 16 exemplifies a learner-agent dialogue tailored to an anatomy lesson.

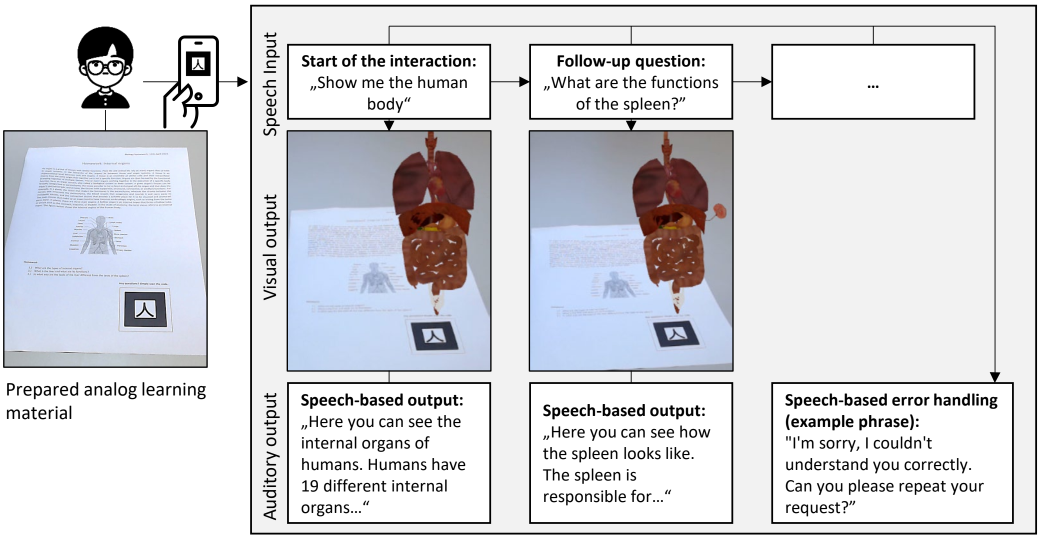


Figure 16. Learner-agent dialogue (Schuir et al. 2022b)

During the preliminary evaluation, 11 teachers and researchers of didactics confirmed the concept's usefulness as a supplement for distance learning settings. Respondents specifically emphasized that the distribution of short auditory stimuli with visualized animations via AR helped stimulate learner motivation and attention. Additionally, they commented that the artifact could relieve teachers by intercepting recurring questions. Since commercially available CA or AR software does not yet integrate such multimodality, the design knowledge can inform learning application providers, ranging from school-based education to professional contexts (Schuir et al. 2022b).

3.3 Value Creation

After developing new technologies, companies must transform them into products or services to create economic value by innovating their business models (Chesbrough 2010). This transformation can occur within a business ecosystem comprising specific roles, such as business partners, suppliers, and customers (Moore 1993). Members of the ecosystem surrounding AR and VR technologies co-create products and services for sectors such as education, healthcare, retail, manufacturing, and construction (Perkins Coie 2021). The German business ecosystem for AR and VR is particularly driven by the advent of the Industry 4.0 initiative. It is thus characterized by a decentralized structure involving well-established companies (e.g., Siemens and Bosch), startups, and research institutes (Bezegová et al. 2018). To answer this dissertation's third research question, Contribution H presents an e^3-value model depicting the market roles and value streams associated with AR and VR technologies. The study draws a qualitative content analysis of 141 startup descriptions obtained from Crunchbase (2021). Figure 17 visualizes the ecosystem model, which contains 24 different market roles and their value streams.

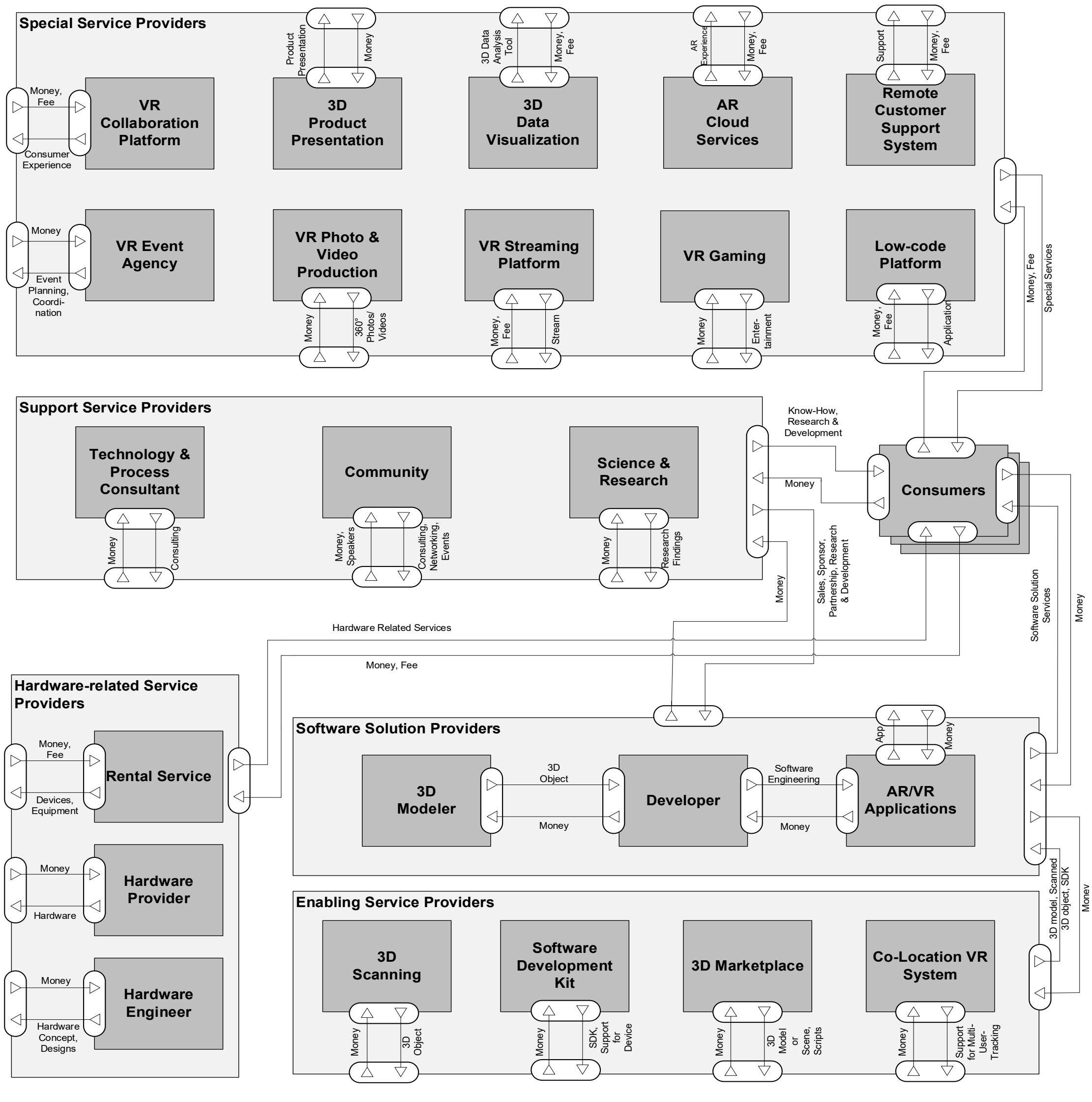


Figure 17. Generic model of the business ecosystem (Schuir et al. 2020)

A qualitative evaluation with six practitioners indicated that the model facilitates understanding of how the actors involved produce, consume, and distribute economic value to commercialize immersive technologies. As such, the model supports the identification of economic niches and collaboration opportunities that can be exploited by co-creating specialized services. For instance, investors can draw on the model to evaluate the allocation of value streams, opportunities, and risks before making investments (Schuir et al. 2020).

4 Discussion

4.1 Implications for Research

The purpose of this cumulative dissertation is to investigate the design, application, and impact of AR and VR systems in the workplace. For this purpose, it pursues three research questions in eight research projects. In line with the framework presented in Section 2.2, these knowledge contributions include user preferences, prescriptive design knowledge, and an e^3-value model. Against this backdrop, this dissertation provides valuable contributions and implications for research, which are outlined in this section.

First, the conjoint analyses (Contribution A and B) improve understanding user preferences regarding AR and VR systems. For design science researchers, the relative importance values, preference patterns, and clusters support the design of artifacts, for instance, by governing the prioritization of user requirements (Naous and Legner 2021). In particular, both conjoint analyses demonstrate users' desire to protect individual data (e.g., tracking, camera, and performance data) from third-party access. While research has identified privacy threats and protection approaches in the domain of AR and VR, best practice policies recommended by research institutions and industry associations remain scarce (Guzman et al. 2019). Leveraging the preferences and combining them with further research, IS scholars can fill this research gap by developing normative privacy policies for members of the business ecosystem (e.g., software solution providers). Besides producing design rationales, the preference patterns have vital implications for technology adoption research. Unlike suggested by the TAM (Davis 1989), AR and VR adoption constitutes a complex phenomenon influenced by multifaceted antecedents, such as safety and privacy concerns, whose impacts differ significantly across heterogeneous users. This insight aligns with the "one-size fits all" (Head and Ziolkowski 2012, p. 2337) criticism of adoption models such as TAM, confirming that AR and VR require technology-specific adoption lenses (e.g., Sagnier et al. 2020). To derive such TAMs, future theory building can leverage the relative importance values. For instance, Contribution B suggests integrating theoretical constructs regarding perceived safety and privacy risks into AR-specific TAMs for the workplace (Schuir and Teuteberg 2021). Striving to better understand which configurations of benefits and risks influence the causal heterogeneity revealed in the cluster analyses, future studies could employ set-theoretic approaches. As an example, fuzzy set qualitative comparative analyses enable researchers to reveal distinct conjunctions of benefits and risks that explain adoption intention (cf. Pappas and Woodside 2021).

Second, the four instantiations and their design knowledge (i.e., the meta-requirements, design principles, and architectures; Contribution C-G) contribute to the design science research knowledge base. According to Gregor and Hevner (2013), each of the four projects presents a Level 2 contribution in terms of a nascent design theory that contains higher-level guidance for the design of AR and VR systems. Due to the novelty of the implemented features (e.g., hand-tracking, object detection, multimodal user interfaces), this design knowledge is expected to provide original contributions. Future studies can adopt, apply, and extend this prescriptive knowledge. The design principles for virtual prototyping may guide design-oriented research in the context of product development, while the design principles for VR-based process modeling could inform the development human-centered workplace design solutions (e.g., virtual fabric planning). Noteworthy, both VR projects indicate that system developers can influence users' cognitive abilities by purposefully manipulating the visual layout of the 3D environment. Contribution D thus applies supraliminal priming by integrating creativity-stimulating elements to foster creative team performance (Vogel et al. 2021), while Contribution E indicates that an excessively detailed environment distracts users from the task at hand (Pöhler et al. 2021). To provide empirically grounded guidance for the layout of 3D environments, future studies should investigate these observations by conducting lab experiments with manipulated 3D environments.

In a similar vein, the design knowledge derived in Contribution F and G might govern future implementations. The concept for AR-based object labeling can be transferred to design-oriented research efforts in the Industry 4.0 domain, where pre-trained AI classifiers are necessary to intelligently augment human capabilities through the automated detection of quality deviations for mass-customized products (Zamora-Hernández et al. 2021). The design principles for multimodal CAs, in turn, may inspire the development of pedagogical CAs for the healthcare sector, where the 3D visualization anatomical structures is associated with enhanced learning success (Moro et al. 2021). Notably, the AR interface introduces a new level of multimodality to the realm of pedagogical CAs, as the visualization capabilities of prior CAs were mainly limited to avatar representation with no support for 3D visualization of learning content.

Conversely, the ten distinct evaluations with more than 110 participants revealed multifaceted insights for the interdisciplinary research community surrounding AR and VR technologies. Contribution D, for instance, reports benchmarking values for the creativity support index and the simulator sickness questionnaire. The latter is of particular interest to human-computer interaction research since Kennedy et al. (1993) originally developed the simulator sickness questionnaire for stationary flight simulators, and research thus far lacks benchmarks for modern VR headsets (Vogel et al. 2021). Moreover, the lab experiments revealed research problems to be addressed in future design science research projects. For instance, the isolating nature of VR headsets renders physical face-to-face communication impossible, which was problematic with novices who struggled to familiarize themselves with the VR headsets (e.g., learning hand gestures). This challenge could be resolved by developing intelligent (i.e., AI-based) user assistance to facilitate familiarization with VR headsets. Such assistance could, for example, automatically identify improperly executed gestures and provide context-sensitive support to the user. Another worthwhile avenue for design science researchers concerns the development of more realistic and natural avatars to facilitate rich remote communications. For instance, it is necessary align avatar movement with advancements in eye, face, and body tracking to enhance the realism of virtual communication through non-verbal cues.

Together, the four design science research projects specify how immersive technologies can be deployed in the future work environment, thus revealing novel insights regarding the interplay of humans, machines, and tasks (cf. vom Brocke et al. 2018). As shown, VR supports organizations along innovation processes, such as design thinking, by allowing them to design and validate new products, services or processes without physically building them. Furthermore, VR-mediated collaboration might help organizations overcome the limitations of 2D remote working tools (e.g., Zoom Fatigue) by providing a more hedonic user experience with a more natural communication. As a result, the implementation of VR is expected to induce tangible and intangible benefits, such as reduced resource and travel costs as well as enhanced employee satisfaction. However, these benefits also face financial risks due to high implementation costs. To support organizations towards investment in VR technologies, future studies should analyze their economic viability by conducting cost-benefit analyses. For this purpose, researchers can leverage utility effect chains combined with cost-benefit analysis to account for intangible benefits (cf. Oesterreich and Teuteberg 2018). The integration of AR into IS, in turn, was found to render high-level image labeling tasks more efficient by providing virtual cues to capture structured data, thereby relieving both workers and crowdsourcing platforms. Despite these efficiency gains, such computer-mediated changes in workflows may also induce negative consequences, such as user resistance (Kim and Kankanhalli 2009) or technostress (Tarafdar et al. 2007). Future studies should examine this "dark side" of AR and VR technologies as part of interdisciplinary research projects in organizations to grasp the social implications as well as to identify and systemize potential countermeasures. For instance, it is worthwhile to develop guidelines for the use of VR in organizations to avoid negative side effects (e.g., technostress, simulator sickness) by limiting the duration of use.

Finally, the e^3-value model (Contribution H) improves understanding the economic effects of AR and VR by aggregating stakeholders and value streams associated with the technical innovations brought to the markets since the advent of Google Glass in 2012. This model emphasizes research's vital role in the business ecosystem, revealing an interdependence between software solution providers and academic disciplines such as IS research. This insight encourages researchers to ensure the visibility of their work through distribution practices such as open-access publications and communication via industry associations (e.g., the XR Association). Moreover, the roles and value streams provide researchers with a unified terminology for classifying artifacts and services. For instance, IS researchers might refer to the model when developing taxonomies for AR- and VR-based business models by applying value streams to deductively classify value propositions.

In summary, this cumulative dissertation contributes multifaceted insights to the body of knowledge. The results help IS scholars and researchers from related disciplines (e.g., psychology, computer science, and management) understand the design, impact, and implications of AR and VR systems in the workplace.

4.2 Implications for Practice

In congruence with the IS discipline's overarching objective of improving the understanding of several economic, societal and political stakeholder groups, such as companies, decision-makers, and regulators, this cumulative dissertation contributes valuable insights for practitioners (Österle et al. 2011). These insights address stakeholders in the business ecosystem for AR and VR technologies, including business consultants, entrepreneurs, investors, regulators, software solution providers, system developers, and organizational decision-makers (Schuir et al. 2020).

First, the user preferences enable members of the business ecosystem to critically assess their soft- and hardware offerings in terms of user-centricity. In particular, the implementation and communication of privacy policies require careful attention to avoid acceptance issues. Contribution A, for instance, encourages VR hard- and software providers to implement customizable privacy settings to mitigate individual privacy concerns since the privacy policy attribute constitutes the most important attribute for 22.22% of the sample. Moreover, Contribution B indicates that implementing safety-enhancing features (e.g., collision detection) represents a valuable extension of head-worn AR systems from the user's perspective due to the limited field of view of AR glasses. Organizational decision-makers, in turn, can leverage the user preferences when making soft- and hardware investment decisions. As shown, users appreciate natural interaction modalities such as hand tracking, and prefer stand-alone devices regarding VR headsets, but require a careful selection of use cases in the context of head-worn AR systems due to privacy and occupational safety concerns. This insight encourages organizations to involve employees, and cautiously select soft- and hardware before rolling out the technologies. Thereby, organizations should involve several different key employees (e.g., from different age groups) to account for the heterogeneity uncovered in the cluster segmentations.

Second, the design science projects inform business consultants and decision-makers in organizations about the capabilities of immersive technologies to shape the future of work, and provide system developers with guidance for the design of IS. The first two projects demonstrate that VR constitutes a well-suited computing platform to support creative and collaborative processes due to its rich visualization capabilities and hedonic user experience. For organizations applying design thinking and workshop facilitators, the creativity support system presented in Contribution D can therefore be a valuable alternative or supplement to physical workshop settings. Against this backdrop, workshop facilitators can innovate their service portfolios and enrich their value proposition by integrating the artifact (Vogel et al. 2021). Moreover, VR can encourage user engagement within process modeling efforts, leading to a more positive attitude towards business process reengineering (Pöhler et al. 2021). The immersive modeling approach is hence well-suited to support industrial companies that are restructuring their processes and production facilities. Process consultants with a dedicated focus on industrial companies might therefore consider enriching their value proposition by integrating immersive modeling approach into their service portfolios (Pöhler et al. 2021). To develop such market offerings, system developers can draw on the design principles presented in this dissertation.

AR technologies, in turn, enable organizations to capture structured image datasets. For crowdsourcing platforms, the proposed system architecture and mobile application can help streamline high-level image labeling tasks. This solution is also transferrable to the Industry 4.0 domain and is of interest for companies (e.g., manufacturers) that intend to implement object detection, but have limited experience with human-in-the-loop operations. Due to the automated training process, the artifact does not require technical background knowledge and thus enables unexperienced humans in the loop to develop CNN models. Further practical implications arise from the multimodal CA. The preliminary evaluation indicates that the combination of AR and CAs constitutes a valuable supplement for distance learning settings in a twofold manner. On the one hand, multimodal CAs allow learners to ask follow-up questions independent of time and location and to respond to these requests by providing 3D visualizations. This benefit is particularly valuable for students from socially disadvantaged families who, for example, receive less parental support in learning. On the other hand, the system may decrease the teacher's workload by reducing the effort to answer repetitive questions, enabling them to focus on other duties such as delivering personalized support for students with learning disabilities. To unfold these potentials, AR software solution providers should collaborate with providers of CAs in order to tap into their synergies. At this stage, both parties can draw on the design principles presented in Contribution G.

Finally, the e^3-value model advances understanding the business ecosystem for AR and VR technologies. It presents a blueprint for identifying strategic resources that startups require to successfully enter the market, for instance, by highlighting the inherent value of 3D modelers along the software development value chain. Moreover, the model helps startups unlock economic niches and exploit synergies between companies. Entrepreneurs can therefore apply the model to analyze their position within the ecosystem or undertake strategic decisions (e.g., regarding human resources, business relationships, and new business divisions). Considering the vitality of science-practice collaborations for technical progress within this ecosystem (Bezegová et al. 2018), policymakers without any industrial background knowledge can leverage the model to become familiar with the AR and VR industry and to devise funding programs for research projects.

In summary, this cumulative dissertation provides valuable insights for organizations seeking to modernize their workplaces, software solution providers, business consultants and other stakeholders of AR and VR technology business ecosystem.

4.3 Limitations and Future Research

Each of the eight contributions contained in this cumulative dissertation passed a double-blind peer review process to ensure scientific quality and practical relevance. Nonetheless, this work is subject to limitations related to generalizability, validity, and objectivity (Shipman 2014). This section discusses these limitations along with worthwhile avenues for future research.

Generalizability addresses the extent to which results are transferable to a broader context (Shipman 2014). This dissertation is limited to the organizational use of immersive technologies and highlights exemplary use cases. Although each use case has practical relevance, this narrow scope limits the generalizability. Future research should broaden the scope by studying the use of AR and VR technologies in other domains. Promising application fields include the support of healthcare professionals (e.g., AR-based support of surgeons), workforce training (e.g., VR-based soft skill training), and industrial prototyping (e.g., VR-based prototyping in the automotive sector). Likewise, the dynamic developments associated with AR and VR constrain the generalizability. For instance, the evaluation findings strongly correlate with the soft- and hardware used. To minimize these biases, attention was paid to leveraging devices with high computing power and reliable software frameworks throughout each design science research project. Nonetheless, future replication studies with more sophisticated devices might lead to divergent findings.

Another limitation associated with generalizability concerns the literature review samples, survey populations, expert interviews, focus groups, and lab experiments. For instance, the lab experiments predominantly involved participants aged between 20 and 30 years. Thus, the participants of the final evaluation in Contribution D reported an affinity for interaction scale index value of 4.59, indicating that they are digitally savvy (Franke et al. 2019). The IS discipline has intensively discussed the role of population bias (Compeau et al. 2012). Replication studies with elderly subjects are likely to produce divergent and arguably inferior evaluation results due to a lack of familiarity with the technologies. Field studies involving more diversified and larger samples in real-world settings (e.g., design thinking workshops) constitute a valuable alternative to the recruitment strategies employed in this dissertation. Due to the hygiene regulations associated with the COVID-19 pandemic, however, it was not possible to conduct field experiments during most of this dissertation (van der Aalst et al. 2020). Future studies should therefore recruit larger and more heterogeneous samples to validate the usefulness of the design knowledge. It would also be worthwhile to examine technology acceptance throughout these studies. For this purpose, researchers can leverage the TAM extensions proposed in Section 4.1.

Validity refers to how the results reflect reality and extant research (Shipman 2014). In this context, one limitation concerns the conjoint analyses' results, which correlate with the stimuli set definition. For example, an uneven distribution of the number of levels can induce the "number-of-levels effect" (Verlegh et al. 2002). Another bias can arise from the order of the chosen scenarios since cognitive performance tends to decrease throughout a survey (Chrzan 1994). Despite the measures taken to reduce these biases (e.g., a randomization of the choice orders), future research should triangulate the conjoint analyses' findings by employing additional research methods (e.g., fuzzy set qualitative comparative analysis). Another limitation addresses the validity of the e^3-value model, which was grounded in publicly available information from the startup database Crunchbase and was limited to German companies. Hence, future research should expand the model by including international companies to exhaustively represent the business ecosystem. The American and Asian markets represent promising avenues as these regions exhibit a disruptive character due to companies such as Oculus and Samsung.

Finally, objectivity concerns the reliability and reproducibility of the studies (Shipman 2014). The literature screening processes, along with the qualitative content analyses are subject to subjective bias. To reduce this bias, both procedures were performed independently by at least two individuals following the interrater agreement, whenever possible (LeBreton and Senter 2008). Nevertheless, vital studies may have been overlooked. Another potential bias concerning objectivity relates to the use of perceptual data. For instance, evaluations can be biased by interpersonal relationships between the participants and experimenters. To reduce this bias, researchers are encouraged to employ objective data. As an example, advanced VR headsets (e.g., HP Reverb G2 Omnicept) enable researchers to measure vital signs, cognitive load, and eye movements to better understand user behavior. Future studies should leverage these capabilities to strengthen the objectivity of their research designs.

5 Conclusion

The overarching purpose of this cumulative dissertation is to investigate the design, application, and impact of AR and VR systems in the workplace. For this purpose, this dissertation studied user preferences and derived design principles for four IT artifacts. In addition, this dissertation introduced an e^3-value model to illustrate the value creation mechanisms associated with the technologies.

With these findings, this cumulative dissertation contributes to the body of knowledge of researchers and practitioners in three ways. First, the empirical analysis of user preferences enables researchers to understand the contextual factors influencing intention to use AR or VR technologies and allows IT providers to tailor their market offerings to heterogeneous user needs. Second, the design science projects revealed that VR constitutes a promising medium to support collaborative activities, such as design thinking and process modeling. AR, in turn, can facilitate the capture of structured image datasets in human-in-the-loop processes and increase the media richness of pedagogical CAs. To exploit these capabilities, researchers and practitioners can draw on the design principles presented in this dissertation. Third, the e^3-value model contributes to a unified understanding of the market actors and value streams associated with AR and VR technologies, providing a blueprint for business model researchers, startups, and investors.

Together, these insights improve understanding the sociotechnical interplay between humans, immersive technologies, and tasks, as well as its economic implications in the future of work. Further research should broaden the scope of this dissertation by elaborating on other use cases and delve deeper into the cost-effectiveness of implementing immersive technologies in order to provide a more holistic understanding of their social and economic implications.

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Part B: Research Contributions

Contribution A	
Title	Zwischen Preisjägern, Datenschützern und Tech-Enthusiasten: Segmentierung des Virtual-Reality- Marktes am Beispiel Oculus
Authors	Julian Schuir Ludger Pöhler Frank Teuteberg
Year	2022
Medium	Journal
Outlet	HMD Praxis der Wirtschaftsinformatik
Ranking	VHB-JOURQUAL 3: D WKWI: B
Bibliographic information	Schuir, J.; Pöhler, L.; Teuteberg F. (2022): Zwischen Preisjägern, Datenschützern und Tech-Enthusiasten: Segmentierung des Virtual-Reality-Marktes am Beispiel Oculus. HMD Praxis der Wirtschaftsinformatik, 59(1), 261-279.
Identification	DOI: 10.1365/s40702-021-00817-w ISSN: 1436-3011
Link	https://link.springer.com/article/10.1365/s40702-021-00817-w
Abstract	Virtual Reality (VR) hat in den vergangenen Jahren erhebliche technologische Fortschritte verzeichnet und begonnen, sich im Endverbrauchermarkt zu etablieren. Insbesondere Facebooks Tochterunternehmen Oculus erzielte mit der Quest 2 hohe Absatzzahlen, wodurch das Produkt zum bisher meistverkauften VR-Headset avancierte. Gleichzeitig entfachte sich aufgrund Oculus neuer Datenschutzbestimmung, welche die Gerätenutzung an ein Facebook-Konto bindet, jedoch ein kontroverser Diskurs unter Datenschützern. Endverbraucher stehen seither vor einem Dilemma. Sie müssen sich zwischen der Preisgabe sensibler Daten an Facebook im Falle der Nutzung kostengünstiger Oculus-Geräte und höheren Preisen anderer VR-Headsets entscheiden. In Deutschland führte diese Entwicklung zu einer Vertriebspause der Quest 2, da das Bundeskartellamt ein Missbrauchsverfahren gegen Facebook eingeleitet hat. Im vorliegenden Beitrag wird auf Basis einer Conjoint-Analyse untersucht, wie deutsche Endverbraucher dieses Dilemma wahrnehmen. Hierzu werden die relativen Wichtigkeiten von Datenschutzbestimmungen, Hardwareeigenschaften und Preisen für Kaufentscheidungen miteinander verglichen. Es ergeben sich drei verschiedene Marktsegmente mit unterschiedlichen Kaufentscheidungsheuristiken. Aus diesen Erkenntnissen resultieren sieben Handlungsempfehlungen, die VR-Herstellern, -Entwicklern, -Nutzern und Verbraucherschützern bei der verantwortungsvollen und weitreichenden Diffusion der VR-Technologie im Endverbrauchermarkt helfen sollen.

Contribution B	
Title	Understanding augmented reality adoption trade-offs in production environments from the perspective of future employees: A choice-based conjoint study
Authors	Julian Schuir Frank Teuteberg
Year	2021
Medium	Journal
Outlet	Information Systems and e-Business Management
Ranking	VHB-JOURQUAL 3: C WKWI: B
Bibliographic information	Schuir, J.; Teuteberg, F. (2021): Understanding augmented reality adoption trade-offs in production environments from the perspective of future employees: A choice-based conjoint study. Information Systems and e-Business Management, 19(3), 1039-1085.
Identification	DOI: 10.1007/s10257-021-00529-0 ISSN: 1617-9846
Link	https://link.springer.com/article/10.1007/s10257-021-00529-0
Abstract	The implementation of augmented reality (AR) systems in production environments is associated with a variety of advantages, such as productivity gains, lower costs and reduced operating times. Despite these potential benefits, the lack of user acceptance due to issues such as privacy concerns constitutes a barrier to diffusion in workplace environments. In order to better understand the issues surrounding AR acceptance, we employed a conjoint study to empirically examine the trade-offs that future employees perceive when being involved in adopting such systems. Using a hierarchical Bayes estimation, we discover that functional benefits such as productivity gains and safety enhancement are the main adoption drivers. In contrast, future employees indeed perceive monitoring through head-worn AR devices as negative. However, a complementary cluster analysis indicates that not all respondents share a negative view of monitoring, and one third are likely to share their performance data with employers. We identify three groups with significantly different utility patterns. Furthermore, we monetize the value of privacy to determine compensation payments. The results may help employers, decision-makers, software solution providers as well as researchers in the information systems domain to better understand the factors surrounding acceptance of AR assistance systems. To the best of our knowledge, we are the first to address this issue using conjoint analysis.

Contribution C	
Title	Gestaltung und Erprobung einer Virtual-Reality-Anwendung zur Unterstützung des Prototypings in Design-Thinking-Prozessen
Authors	Jannis Vogel Julian Schuir Oliver Thomas Frank Teuteberg
Year	2020
Medium	Journal
Outlet	HMD Praxis der Wirtschaftsinformatik
Ranking	VHB-JOURQUAL 3: D WKWI: B
Bibliographic information	Vogel, J.; Schuir, J.; Thomas, O.; Teuteberg, F. (2020): Gestaltung und Erprobung einer Virtual-Reality-Anwendung zur Unterstützung des Prototypings in Design-Thinking-Prozessen. HMD Praxis der Wirtschaftsinformatik, 57(3), 432-450.
Identification	DOI: 10.1365/s40702-020-00608-9 ISSN: 1436-3011
Link	https://link.springer.com/article/10.1365/s40702-020-00608-9
Abstract	Um in zunehmend komplexen und wettbewerbsintensiven Märkten konkurrenzfähig bleiben zu können, muss die Innovationskraft eines Unternehmens sichergestellt werden. Dabei kommt dem Menschen und seiner Kreativität eine zentrale Rolle zu. Design Thinking bietet ein Methodenspektrum, um die Kreativität von Einzelnen in einem gruppendynamischen, benutzerzentrierten Prozess in Innovationen zu überführen. Es kommen insbesondere spielerische Ansätze zur Kreativitätsförderung zum Einsatz, zu denen beispielsweise das Lego-Prototyping gehört. Digitale Unterstützungswerkzeuge sind bisher selten, obwohl sowohl Forschung als auch Praxis die virtuelle Realität aufgrund ihres immersiven Charakters zunehmend als ein Kreativitätsmedium betrachten. Im vorliegenden Beitrag wird daher eine Virtual-Reality-Anwendung zur Unterstützung des Prototypings in Design-Thinking-Prozessen als ein Proof of Concept vorgestellt und im Rahmen einer Case-Study evaluiert. Im Ergebnis resultiert eine Virtual-Reality-Umgebung, die einen positiven Effekt auf das Design-Thinking-Prototyping hinsichtlich der Kreativitätsförderung, der Effizienz und der Intuition hat. Hervorgehend aus den Evaluationsergebnissen entstehen Ansätze für eine folgende Iteration sowie Handlungsempfehlungen für die Gestaltung und den Einsatz unternehmensbezogener VR-Anwendungen. Perspektivisch gesehen eröffnen VR-Anwendungen neue Potenziale zur Gestaltung von digitalisierten Arbeitswelten.

Contribution D	
Title	Let’s Do Design Thinking Virtually: Design and Evaluation of a Virtual Reality Application for Collaborative Prototyping
Authors	Jannis Vogel Julian Schuir Cosima Koßmann Oliver Thomas Frank Teuteberg Kai-Christoph Hamborg
Year	2021
Medium	Conference Proceedings
Outlet	29th European Conference on Information Systems (ECIS 2021)
Ranking	VHB-JOURQUAL 3: B WKWI: A
Bibliographic information	Vogel, J.; Schuir, J.; Koßmann, C.; Thomas, O.; Teuteberg, F.; Hamborg, K.-C. (2021): Let's Do Design Thinking Virtually: Design and Evaluation of a Virtual Reality Application for Collaborative Prototyping. Proceedings of the 29th European Conference on Information Systems (ECIS 2021), A Virtual AIS Conference.
Identification	DOI: - ISBN: 978-1-7336325-6-0
Link	https://aisel.aisnet.org/ecis2021_rp/112
Abstract	Design Thinking (DT) is a widely used approach to develop human-centric solutions in organizational settings. One of the main activities within DT is prototyping, which allows for visualizing design ideas. However, the geographical distribution of teams and the lack of suitable working environments challenge these practices. This paper presents a design science research project that resolves these issues through virtual reality. Drawing on findings for creativity support, we derive meta-requirements and design principles and develop the DTinVR application that allows teams to visualize their ideas based on gestural interaction. To the best of our knowledge, we are the first to enable collaborative prototyping using hand tracking. We confirm the effectiveness and positive usability of DTinVR by means of three evaluations and discuss how our design principles can help to develop immersive solutions. The findings of this study contribute to the design knowledge on immersive applications in the information systems discipline.

Contribution E	
Title	Let's Get Immersive: How Virtual Reality Can Encourage User Engagement in Process Modeling
Authors	Ludger Pöhler Julian Schuir Pascal Meier Frank Teuteberg
Year	2021
Medium	Conference Proceedings
Outlet	42nd International Conference on Information Systems (ICIS 2021)
Ranking	VHB-JOURQUAL 3: A WKWI: A
Bibliographic information	Pöhler, L.; Schuir, J.; Meier, P.; Teuteberg, F. (2021): Let's Get Immersive: How Virtual Reality Can Encourage User Engagement in Process Modeling; Proceedings of the 42nd International Conference on Information Systems (ICIS 2021), Austin, USA.
Identification	DOI: - ISBN: 978-1-7336325-9-1
Link	https://aisel.aisnet.org/icis2021/user_behaivors/user_behaivors/12
Abstract	Business process modeling plays a fundamental role in organizations that are restructuring their processes to meet the challenges of increasing digitalization and globalization. However, the geographic distribution of process stakeholders, the abstract non-contextual modeling languages, and the resulting low motivation to participate make process modeling difficult. In this paper, we present a design science research approach that resolves these problems using virtual reality. Based on empirical evidence, we first developed design principles to increase employee engagement. Subsequently, a virtual reality application was generated, that enables the placing of process models in realistic and immersive working environments. We developed the application continuously in four evaluation cycles and finally tested it in terms of usefulness in three field studies. The results of this study contribute to more context awareness in business process management and provide design knowledge for future industrial virtual reality applications.

Contribution F	
Title	Augmenting Humans in the Loop: Towards an Augmented Reality Object Labeling Application for Crowdsourcing Communities
Authors	Julian Schuir René Brinkhege Eduard Anton Thuy Duong Oesterreich Pascal Meier Frank Teuteberg
Year	2021
Medium	Conference Proceedings
Outlet	16th International Conference on Wirtschaftsinformatik (WI 2021)
Ranking	VHB-JOURQUAL 3: C WKWI: A
Bibliographic information	Schuir, J.; Brinkhege, R.; Anton, E.; Oesterreich, T. D.; Meier, P.; Teuteberg, F. (2021): Augmenting Humans in the Loop: Towards an Augmented Reality Object Labeling Application for Crowdsourcing Communities; Proceedings of the 16th International Conference on Wirtschaftsinformatik (WI 2021), Essen, Germany.
Identification	DOI: - ISSN: -
Link	https://aisel.aisnet.org/wi2021/QDesign/Track10/5/
Abstract	Convolutional neural networks (CNNs) offer great potential for business applications because they enable real-time object recognition. However, their training requires structured data. Crowdsourcing constitutes a popular approach to obtain large databases of manually-labeled images. Yet, the process of labeling objects is a time-consuming and cost-intensive task. In this context, augmented reality provides promising solutions by allowing an end-to-end process of capturing objects, directly labeling them and immediately embedding the data in training processes. Consequently, this paper deals with the development of an object labeling application for crowdsourcing communities following the design science research paradigm. Based on seven issues and twelve corresponding meta-requirements, we developed an AR-based prototype and evaluated it in two evaluation cycles. The evaluation results reveal that the prototype facilitates the process of object detection, labeling and training of CNNs even for inexperienced participants. Thus, our prototype can help crowdsourcing communities to render labeling tasks more efficient.

Contribution G	
Title	Tell Me and I Forget, Involve Me and I Learn: Design and Evaluation of a Multimodal Conversational Agent for Supporting Distance Learning
Authors	Julian Schuir Eduard Anton Marian Eleks Frank Teuteberg
Year	2022
Medium	Conference Proceedings
Outlet	17th International Conference on Wirtschaftsinformatik (WI 2022)
Ranking	VHB-JOURQUAL 3: C WKWI: A
Bibliographic information	Schuir, J.; Anton, E.; Eleks, M.; Teuteberg, F. (2022): Tell Me and I Forget, Involve Me and I Learn: Design and Evaluation of a Multimodal Conversational Agent for Supporting Distance Learning; to appear in: Proceedings of the 17th International Conference on Wirtschaftsinformatik (WI 2022), Nürnberg, Germany.
Identification	DOI: - ISSN: -
Link	https://aisel.aisnet.org/wi2022/digital_education/digital_education/2/
Abstract	The COVID-19 pandemic has shifted children's learning routines from schools to their own homes, necessitating learning support solutions. This paper reports on a design science research project that combines augmented reality with a conversational agent to assist schoolchildren in learning complex subjects by providing verbal descriptions and interactive animations. Drawing on the theoretical foundations of multimedia learning, we derive three design principles to resolve seven issues associated with distance learning. The instantiated artifact augments text-based learning resources and facilitates learning in a context-sensitive manner through multimodal output. The proof-of-concept evaluation with 11 experienced teachers and researchers in the field of didactics confirms the usefulness of these design principles and suggests refinements of the artifact.

Contribution H	
Title	Understanding the Augmented and Virtual Reality Business Ecosystem: An e^3-value Approach
Authors	Julian Schuir Jannis Vogel Frank Teuteberg Oliver Thomas
Year	2020
Medium	Conference Proceedings
Outlet	Lecture Notes in Business Information Processing
Ranking	VHB-JOURQUAL 3: C WKWI: -
Bibliographic information	Schuir, J.; Vogel, J.; Teuteberg, F.; Thomas, O. (2020). Understanding the Augmented and Virtual Reality Business Ecosystem: An e^3-value Approach. In: Shishkov B. (eds) Business Modeling and Software Design. BMSD 2020. Lecture Notes in Business Information Processing, vol 391. Springer, Cham.
Identification	DOI: 10.1007/978-3-030-52306-0_15 ISBN: 978-3-030-52305-3
Link	https://link.springer.com/chapter/10.1007/978-3-030-52306-0_15
Abstract	In recent years, augmented and virtual reality have increasingly gained attention. To date, a multitude of solutions has been developed and implemented both in research and in practice. As a result, these technologies create new business opportunities. Particularly in Germany, a variety of startups tried to enter the market. By analyzing 141 tech startups, this paper visualizes the 25 generic roles and value streams within the augmented and virtual reality business ecosystem using the e^3-value method. Furthermore, we evaluate the model with semi-structured interviews to verify validity. Practitioners can use the model to identify competitors or collaboration opportunities. Theoretically, our research contributes to the body of knowledge by systematically depicting the services related to augmented and virtual reality. Finally, we provide directions for future research.